TOTAL MAXIMUM DAILY LOAD FOR SEDIMENT

SQUAW CREEK, PLACER COUNTY

PUBLIC REVIEW DRAFT

Staff Report

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EXECUTIVE SUMMARY

Squaw Creek is located in an 8.2 square mile alpine watershed approximately six miles northwest of Lake Tahoe in Placer County between Tahoe City and Truckee. The creek was placed on the Clean Water Act Section 303(d) list of impaired waters in 1992. The California Regional Water Quality Control Board, Lahontan Region (Regional Board) has developed this total maximum daily load (TMDL) for sediment in Squaw Creek.

TMDLs are strategies to ensure attainment of water quality standards. They are implemented through existing regulatory and non-regulatory programs to control pollutant discharges from point sources (e.g., discharges from wastewater treatment plants) and nonpoint sources (e.g., sediment discharges from land use activities). The Squaw Creek TMDL focuses on controlling sources of sediment from land use categories identified as major contributors to excessive in-stream sediment loading.

Water quality objectives addressed in the Squaw Creek TMDL pertain to sediment, settleable materials, suspended materials and turbidity. The beneficial uses most sensitive to excessive sedimentation are those related to cold, freshwater aquatic life habitat. The loading capacity and allocations are set to meet water quality objectives and protect sensitive beneficial uses.

The Squaw Creek TMDL includes the following components:

- Problem Statement
- Numeric Targets
- Source Analysis
- Linkage Analysis
- TMDL and Load Allocations
- Margin of Safety
- Implementation and Monitoring

Summaries of each component are provided below.

PROBLEM STATEMENT

Documented in-stream problems in Squaw Creek include degraded benthic invertebrate communities (bottom dwelling organisms such as insects and worms) and physical channel conditions. Accelerated hillslope erosion from land disturbance related to development in naturally erosion-prone areas contribute to excess sediment delivery to the creek. Stream channel erosion, road sanding operations and naturally occurring erosion also contribute to sediment loading to the creek.

The magnitude and extent of the sedimentation impairment was determined based on bioassessment studies conducted in 2000 and 2001 by researchers from the UC Santa Barbara

Sierra Nevada Aquatic Research laboratory (SNARL). As part of the bioassessment, the abundance and diversity of benthic macroinvertebrates (aquatic organisms at least one-half millimeter in size) and substrate particle size were evaluated as measures of aquatic life health and stream channel conditions, respectively. The sedimentation impairment is most apparent in the low gradient meadow reach of Squaw Creek, where the high gradient north and south forks deposit sediment transported from the upper watershed.

As summarized in the following table, the biological data show that Squaw Creek's meadow reach has degraded aquatic life (represented by the biologic condition scores) compared with nearby reference streams (physically comparable stream sites exhibiting conditions associated with minimally disturbed landscapes).

Comparison of Squaw Creek Low Gradient Meadow Reach Biologic Conditions Scores to Low Gradient Reference Streams in Middle Truckee River Watershed

Site	Biologic Condition Score
Squaw Creek upper meadow – 2000	9
Squaw Creek middle meadow – 2000	9
Squaw Creek lower meadow – 2000	11
2000 Squaw Creek Low Gradient Stream Average	**10 (n=3)**
2000 Low Gradient Reference Sites Average	**32 (n=4)**
Squaw Creek upper meadow – 2001	Not Sampled
Squaw Creek middle meadow – 2001	23
Squaw Creek lower meadow – 2001	17
2001 Squaw Creek Low Gradient Stream Average	**20 (n=2)**
2001 Low Gradient Reference Sites Average	**27 (n=6)**

Average biologic conditions scores for the meadow reach in 2000 were 70 percent lower than the average score for the reference sites. However, flows in Squaw Creek were noted to be discontinuous in 2000 and samples were collected at the head or tail of pools because no riffle habitat was present. Average biologic condition scores for the Squaw Creek meadow reach sites showed 100 percent improvement in 2001 when flows were continuous, but were still below the average score for the reference sites by approximately 25 percent.

Sediment-related stream data were collected from Squaw Creek TMDL sites and reference stream sites to correlate modeled sediment load estimates to in-stream measures of sediment deposition and biologic community observations. Deposited fine sediment (less than 1 millimeters in diameter) appears to be particularly problematic, as Squaw Creek meadow sites showed smaller median particle size and larger average percentages of fines and sand when compared to low gradient reference stream sites such as Perazzo Creek, Cold Creek, Independence Creek and the Little Truckee River. Particle size distribution is an important indicator of habitat suitability for aquatic life, and these data indicate that Squaw Creek's channel substrate has degraded substrate conditions compared to the reference sites, indicative of less desirable habitat for aquatic life

Data from the bioassessment studies indicate that the narrative water quality objectives for sediment and settleable materials are not fully met, contributing to the impairment of at least the COLD, SPWN, REC-1, REC-2, WILD, MIGR, and COMM beneficial uses.

NUMERIC TARGETS

Because the sediment-related water quality objectives are narrative statements rather than numeric criteria, it is necessary to develop numeric targets to interpret these objectives. The Squaw Creek TMDL uses in-stream indicators that relate to sedimentation. Indicators are measurable characteristics that can be used to determine the relationship between pollutant sources and their impacts to water quality. Once an indicator is selected, a target value that represents the desired condition of the waterbody is established. For the Squaw Creek TMDL, these include physical habitat measures of stream substrate quality (median particle size and percent fines and sand), and biological parameters that represent desired stream habitat conditions for fish and aquatic invertebrates, established by comparison to regional reference streams sites.

The numeric targets developed for the Squaw Creek sediment TMDL are summarized below.

Indicators and Targets for Squaw Creek TMDL

Indicator	Target Value	Notes
Physical Habitat: D-50 Particle Size	Increasing trend in D-50 value approaching 40 millimeters (mm) or greater.	Represents desired substrate conditions for aquatic life. Target value based on regional reference stream substrate conditions.
Physical Habitat: Percent Fines and Sand	Decreasing trend in percent fines and sand approaching 25% cover of the stream bottom or less.	Represents desired substrate conditions for aquatic life. Target value based on regional reference stream substrate conditions.
Biologic Health: Biological Condition Score, calculated from Index of Biologic Integrity (See Appendix B for more details).	Biologic condition score of 25 or more when flows are continuous.	Represents desired biologic integrity of stream, protective of aquatic life uses. Target value equals 23rd percentile of regional reference stream biologic condition scores.

SOURCE ANALYSIS

The source analysis identifies and quantifies the relative contributions of sediment sources to Squaw Creek. Data collection focused on quantifying erosion rates and sediment transport processes from hillslopes to the stream channel, as well as evaluating in-stream sediment contributions. The estimated existing sediment load for the watershed is 37,900 tons per year.

The contribution of sediment from hillslope sources is divided among categories as shown in the table below. The source analysis indicates that approximately 60 percent of the sedimentation affecting Squaw Creek is related to disturbance brought on by human activities.

Sediment Delivery Estimates, Squaw Creek Watershed
(Rounded to nearest 100 tons)

Sediment Source Category	Total Sediment Delivery by Source Category (tons/year)	Percent of Total by Source Category
Dirt Roads	**9,300**	25%
Major Dirt Road Cuts	**900**	2%
Road Traction Sand	**300**	1%
Residential/Commercial Areas	**200**	1%
Graded Ski Runs	**9,000**	24%
Alluvial Channel Erosion	**4,300**	11%
Undisturbed Areas	**14,000**	37%
*Uncontrollable Sources**	**16,100**	42%
Controllable Sources	**21,800**	58%
Total Annual Sediment Delivery	**37,900**	100%

*This is considered the best estimate of current naturally occurring sediment delivery. The estimate shown includes 50 percent (rounded to 2,100 tons/year) of the annual channel bank contribution and 100 percent (14,000 tons/year) of sediment delivery from undisturbed areas.

LOADING CAPACITY AND LINKAGE ANALYSIS

The loading capacity is an estimate of how much sediment Squaw Creek can assimilate on a yearly basis and still meet water quality objectives and support beneficial uses. The loading capacity is based on comparisons of biologic conditions in Squaw Creek and target conditions found in reference streams. This comparison suggests that a 25 percent reduction in the overall sediment loading of 37,900 tons per year is needed to protect beneficial uses. Therefore, the loading capacity is 28,425 tons per year.

The linkage analysis establishes a relationship (linkage) between the numeric targets and the estimated sediment loading. This linkage makes it possible to determine the capacity of the waterbody to assimilate sediment and still support its beneficial uses. Linkage between sediment delivery to the creek and impairment of aquatic life beneficial uses was based on best professional judgment, modeled loading estimates, and sediment related in-stream physical habitat parameters that correlate with biologic conditions evaluated by SNARL.

TMDL AND LOAD ALLOCATIONS

The TMDL is the sum of wasteload allocations for point sources, load allocations for nonpoint sources, and a margin of safety. The allowable sediment load (i.e., the load capacity) is distributed among the existing controllable sediment source categories, future growth and an explicit margin of safety.

There are currently no National Pollutant Discharge Elimination System (NPDES)-regulated point sources in the watershed; therefore, the wasteload allocation is zero. However, NPDES permits to control stormwater discharges may be issued in the future (e.g., to public facilities that incorporate source areas such as paved roads and parking lots). In that event, the currently assigned load allocation(s) to those source categories would be expressed as wasteload allocation(s) in the permit.

The allocations reflect conservative assumptions about the efficiency of Best Management Practices (BMPs) to control sedimentation. No reduction in sediment delivery from undisturbed lands is assigned. A summary of the TMDL, load allocations, and required load reductions is presented in the following table.

TMDL, Allocations and Percent Reductions Needed by Sediment Source Category

Sediment Source Category	Sediment Delivery by Source Category (Tons/year)	Percent Reduction Required	Load Allocation* (Tons/year)
Dirt Roads	9,300	60%	3,700
Dirt Road Cuts	900	50%	450
Road Traction Sand	300	25%	200
Residential/Commercial Areas	200	25%	150
Graded Ski Runs	9,000	50%	4,500
Alluvial Channel Erosion (50 percent of the total load from channel bank erosion is assumed to be controllable)	2,100	10%	1,900
Total Controllable Sources	***21,800***	***50%***	***10,900***
Alluvial Channel Erosion (50 percent of the total load from channel bank erosion is assumed to be naturally occurring)	2,100	0%	2,100
Undisturbed Areas	14,000	0%	14,000
Total Uncontrollable Sources	***16,100***	***0%***	***16,100***
Total Existing Sediment Load	37,900	Load Allocation to Existing Sources	27,000
Overall Reduction Needed to Achieve TMDL	25%	Load Allocation to Future Growth	150
TMDL = LA (existing and future sources) + MOS	**28,425**	Load Allocation to Margin of Safety (4%)	1,275
		Total Load Allocations	**28,425**

*Allocations to existing sources rounded to nearest 50 tons.

MARGIN OF SAFETY, SEASONAL VARIATIONS, AND CRITICAL CONDITIONS

The margin of safety accounts for information gaps or uncertainty in the TMDL analysis. An explicit or implicit margin of safety may be used. An explicit margin of safety is established by reserving (not allocating) part of the total loading capacity, thereby requiring greater load reductions from existing and/or future source categories. An implicit margin of safety incorporates conservative assumptions in the TMDL analysis. The Squaw Creek TMDL includes both an implicit and explicit margin of safety.

Conservative assumptions were incorporated into data interpretations throughout the TMDL as described in Section 7 of the TMDL. The explicit margin of safety was established by reserving a percentage of the loading capacity to offset uncertainties in the analysis.

The Squaw Creek TMDL accounts for critical conditions by establishing targets based on net long-term effects to the most sensitive reach of Squaw Creek. The TMDL also includes a monitoring and review program that allows for future revisions to the TMDL if needed.

IMPLEMENTATION AND MONITORING PLAN

The Implementation plan relies on compliance with the existing regulatory requirements in place in the watershed with additional focus on certain key issues, and proposes actions to address sediment discharges that are not currently regulated. These actions include Waste Discharge Requirements (WDRs), waivers of WDRs and Basin Plan discharge prohibitions. This approach is consistent with State Water Resources Control Board's *Policy for the Implementation and Enforcement of the Nonpoint Source Pollution Control Program*, which requires Regional Boards to regulate all nonpoint sources of pollution.

WDRs issued to existing dischargers in the watershed currently contain comprehensive requirements to control sediment discharges. These requirements specify that dischargers must identify erosion control problems, propose projects to address the problem, and maintain those projects. Recent enforcement actions focused on the need to comply with these requirements. Because the TMDL process identified fine sediment as a particular concern, source control BMPs to control erosion on hillslopes and limit the delivery of fine sediment to Squaw Creek will be emphasized to fulfill permitting requirements. New WDRs will follow the template set by the existing permits.

Progress toward meeting the TMDL will be determined through monitoring of the in-stream physical and biological parameters identified in the numeric targets section and tracking compliance with existing and proposed regulatory actions. The monitoring and reporting programs for existing permits in the watershed will be updated to require monitoring of these numeric targets, and any new permits for ongoing stormwater, sediment and erosion management will incorporate these monitoring parameters as well. Monitoring and reporting requirements provide the mechanism for the Regional Board, dischargers, and public to determine if the Implementation plan is achieving the TMDL, or if other actions are required. A summary of the requirements is presented in the following tables.

Numeric Target Monitoring Plan

Indicators and Target Values	Monitoring Specifications	Responsible Monitoring Parties	Schedule
Physical Habitat Indicator: D-50 Particle Size. **Target Value:** Increasing trend approaching 40 mm or greater. **Physical Habitat Indicator:**	1. Establish 3 sampling sites (upper, middle, and lower) on the meadow reach of Squaw Creek 2. Conduct bioassessment sampling and	• Squaw Valley Ski Corporation (existing permit) • Resort at Squaw Creek (existing permit) • Village at Squaw Creek	1. Regional Board to add monitoring requirements to existing WDR Monitoring & Reporting programs of permitted dischargers no later than six months after final approval of TMDL. 2. Regional Board to issue WDRs for Placer County stormwater

Indicators and Target Values	Monitoring Specifications	Responsible Monitoring Parties	Schedule
Percent fines and sand. **Target Value:** Decreasing trend approaching 25 percent. **Biologic Health Indicator:** Biologic condition score, based on bioassessment data. **Target Value:** Biologic condition score of 25 or greater.	calculate biologic condition score using Herbst (2002) protocol. 3. Analyze physical habitat indicators using Herbst protocols. 4. All sampling protocols will be specified in WDRs.	(existing permit) • Placer County (anticipated permit)	discharges no later than six months after final approval of TMDL. 3. Each regulated discharger to conduct sampling individually or as agreed to cooperatively. 4. Numeric target sampling shall be conducted once every two years between the months of July and September when flow is continuous. 5. Progress toward attainment of the physical habitat targets to be evaluated by trend assessment, beginning after 3 consecutive sampling events have been completed. Trend assessment will be based on all monitoring data for each physical habitat indicator. 6. Attainment of the biologic condition score target will be assessed using 3-(sampling) event rolling average datasets. The biologic condition target will be met when the rolling average for three consecutive 3-event datasets meets or exceeds 25.

Compliance Monitoring of Erosion and Sediment Control Requirements(1)

Monitoring Parameter	Responsible Monitoring Party	Monitoring Schedule
Compliance with all permit requirements, including discharge specifications, BMP installation and maintenance, general requirements and prohibitions, monitoring, and reporting.	Regional Board staff	Assess permit compliance quarterly using Regional Board's permit tracking database currently in place. Assessment of numeric target data (collected as specified in permits) will occur according to schedule outlined in the table above.
Facilities inspections to ensure permit compliance.	Regional Board staff	Regional Board staff to inspect all facilities twice annually.
TMDL data review and assessment.	Regional Board staff	As outlined in Section 9.4.

(1) Requirements may already be satisfied under existing WDRs.

1. INTRODUCTION

The Lahontan Regional WaterQuality Control Board (Regional Board) is the California state agency responsible for water quality protection east of the Sierra Nevada crest. It is one of nine Regional Boards in California, each generally separated by hydrological boundaries. Each Regional Board consists of nine governor-appointed members who serve four-year terms. The Regional Board, under its federally designated authority, administers the Clean Water Act (CWA) within the Lahontan Region.

In accordance with the CWA, the Regional Board has adopted the *Water Quality Control Plan for the Lahontan Region* (Basin Plan) that specifies water quality standards for waters in the Lahontan Region and implementation measures to enforce those standards. Section 305(b) of the CWA mandates biennial assessment of the nation's water resources to identify and list waters not meeting their water quality standards. These waters are listed in accordance with CWA Section 303(d) and the list is commonly referred to as the 303(d) list. The CWA requires states to establish a priority ranking for impaired waters and to develop and implement Total Maximum Daily Loads (TMDLs) to address the impairments.

A TMDL is a written, quantitative assessment of water quality problems and contributing pollutant sources. It identifies one or more numeric targets for restoring beneficial uses based on applicable water quality standards, specifies the maximum pollutant load that can be discharged and still meet water quality standards, allocates pollutant loads among sources in the watershed and provides a basis for taking actions needed to meet the numeric target(s) and water quality standards.

Squaw Creek is a tributary of the middle Truckee River (the segment between the outlet of Lake Tahoe and the California/Nevada state line), located in the southwest portion of the Truckee River Hydrologic Area (HA No. 635.20). In 1991, The Regional Board adopted Resolution No. 6-91-937 (Lahontan RWQCB, 1991), approving revisions to the Regional Water Quality Assessment database, including the recommended addition of Squaw Creek to the 303(d) list. The recommendation was based on a description of elevated sediment levels in the creek (Woyshner and Hecht, 1987) and information from the California Department of Fish and Game (Messersmith, 1990) that identified substrate and fish habitat loss in Squaw Creek due to siltation. Results from subsequent watershed assessment work indicate that Squaw Creek's sediment load exceeds that expected for the watershed. Studies also indicate that benthic macroinvertebrate communities in portions of Squaw Creek have decreased populations and diversity of pollution-sensitive taxonomic groups (taxa), and low diversity in general, compared to regional reference conditions.

The Regional Board proposes to amend its Basin Plan to incorporate a TMDL and Implementation plan to address sedimentation problems in the watershed adversely affecting water quality. This TMDL report was developed from results of watershed investigations conducted in 2000-2002 and describes the scientific and technical basis for confirming sediment impacts, developing numeric targets, determining sediment sources, and establishing watershed loading capacity.

2. PROBLEM STATEMENT

Information from a variety of sources indicates that, in comparison with other streams in the Truckee River Basin with similar characteristics and less watershed disturbance, the water quality and beneficial uses of Squaw Creek have been adversely affected by various environmental stressors, including excess sediment delivery from developed land uses in the watershed. In-stream impacts include degraded benthic macroinvertebrate communities and evidence of diminished physical habitat for aquatic life. The information suggests that historical and current land uses, stream channel modifications, soil disturbance in naturally erosion-prone areas and diminished stream flows are all contributing factors to the degraded conditions for aquatic habitat in Squaw Creek.

Although factors other than excessive sedimentation may also be affecting aquatic communities in Squaw Creek, this TMDL focuses on sediment, the pollutant for which the creek is listed under Section 303(d). It does not address other factors that may be affecting beneficial uses. For example, studies (Slade & Associates, 1998; West Yost & Associates, 2001; and West Yost & Associates, 2005) suggest that there is a connection between groundwater pumping for domestic and municipal use and surface water flow conditions in the creek. While water quantity issues have the potential to cause negative impacts on beneficial uses, sediment-related issues alone make habitat conditions sub-optimal for aquatic organisms in Squaw Creek.

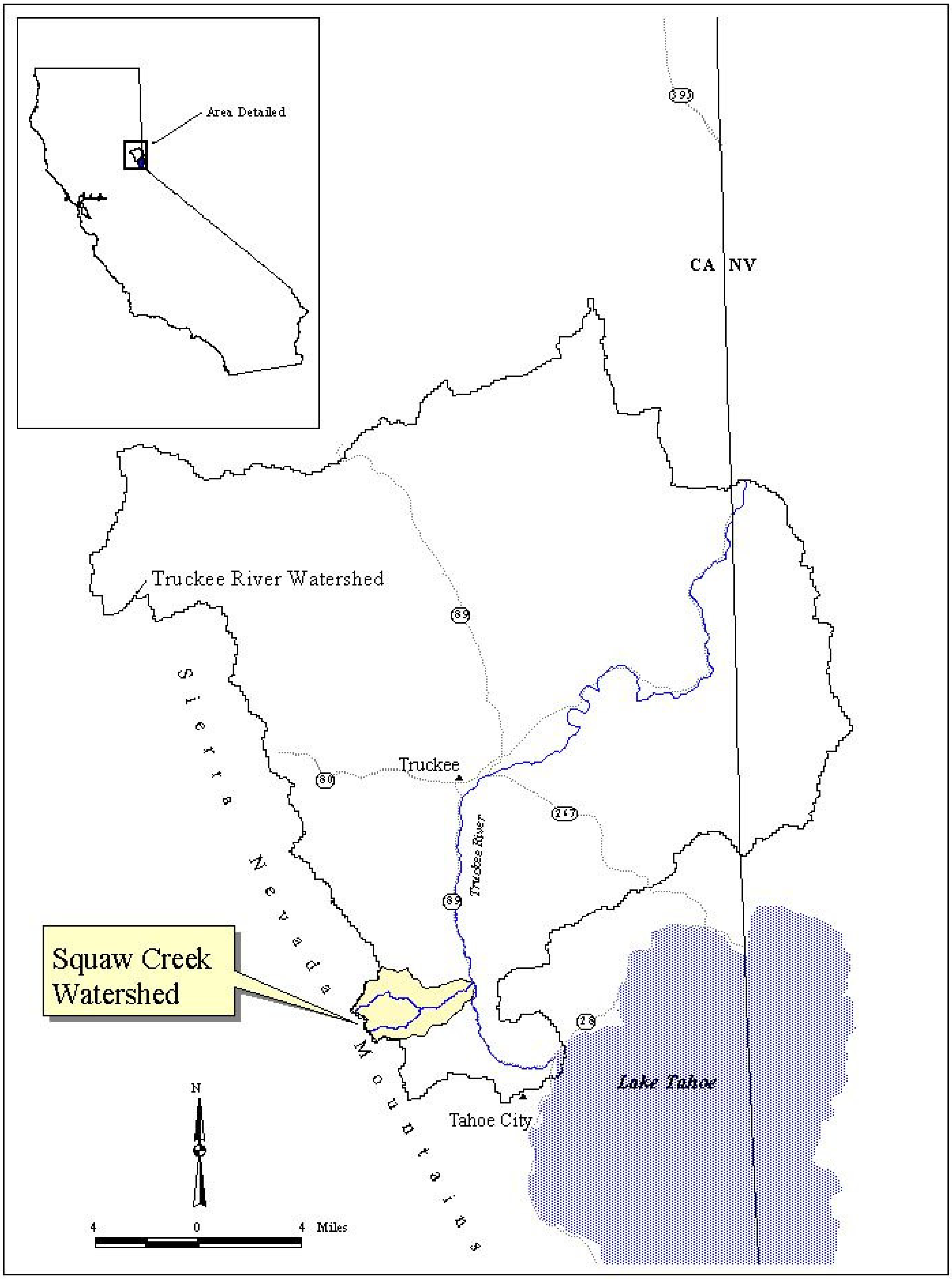
2.1 DESCRIPTION OF THE WATERSHED

2.1.1. General Description and Land Use

The Squaw Creek watershed is located six miles northwest of Lake Tahoe in Placer County, between the towns of Tahoe City and Truckee. Figure 2-1 depicts the location of the Squaw Creek watershed in east-central California. The watershed is about 8.2 square miles in area, with glaciated topography ranging in elevation from 9,006 feet above mean sea level (amsl) at the top of Granite Chief in the western portion of the watershed to 6,120 feet amsl at the confluence of Squaw Creek and the Truckee River. The creek system includes north and south forks in the upper, western part of the watershed that converge to form a single, lower-gradient reach referred to as the meadow reach. The creek then passes over a terminal glacial moraine and descends more steeply until it joins the Truckee River in the eastern portion of the watershed.

The Squaw Creek watershed was used for cattle ranching, sheep herding and logging from the late 1800s through the first half of the 20th century. Ski lifts were first constructed in the south fork watershed in 1949, and later, facilities were expanded to accommodate the 1960 Winter Olympic Games. The meadow reach was modified by the United States Army Corps of Engineers (USACE) to create a temporary parking lot for the 1960 Winter Olympics. The modifications included grading a majority of the meadow, removing boulders, trees and native vegetation, and installing layers of sawdust, woodchips and gravel over the surface. The USACE also installed culverts and drainage pipes to carry runoff away from the parking lot. During this same period, service roads were constructed in the meadow reach and in the south fork as part of ski area development (Poulsen, 1984).

Figure 2-1
Location of the Squaw Creek Watershed



The Resort at Squaw Creek was constructed at the southeast portion of the meadow reach in 1989 and 1990, and includes a golf course, hotel, and resort facilities. The hillside immediately south of the Resort at Squaw Creek was also subdivided during this time and includes approximately 30 acres of residential development. The hillside north of the meadow reach was subdivided in the early 1950s and includes approximately 200 acres of residential development. A pedestrian village was constructed at the western end of the meadow reach in 2000 and it is planned to eventually include 640 townhouses, 80 stores and restaurants, and underground parking. Other existing structures at the western end of the meadow include a cable car building, ski area facilities, and commercial and residential structures. Much of this area is paved and used for parking.

Land in the south fork of Squaw Creek is largely owned by the Squaw Valley Ski Corporation (SVSC), operators of the Squaw Valley USA ski area. The ski area includes approximately 30 ski lifts, a funitel (a type of enclosed aerial lift) and cable car, the High Camp and Gold Coast complexes of restaurants, shops, and visitor services. Ski runs, maintenance roads, and hiking trails have been constructed as part of the resort.

Land in the north fork of Squaw Creek is generally undeveloped. About half the land in the north fork subwatershed is owned by the U.S. Forest Service (USFS), with the remainder owned by private interests. Land uses include approximately six acres of mixed use residential and resort facilities located near the confluence of the north and south forks of Squaw Creek. A small portion of the Squaw Valley USA ski area is also located in the westernmost part of the north fork sub-watershed. These ski facilities include four ski lifts and approximately 50 acres of graded ski runs and maintenance roads. A limited network of dispersed hiking trails follows the north fork of Squaw Creek to Shirley Lake.

The Squaw Valley General Plan allows growth to reach a seasonal overnight residential population of 12,000 and a maximum skier capacity of 17,500 per day. Statistics for 1997, included in the Village at Squaw Valley USA Environmental Impact Report (EIP Associates, 1999), indicate that the Squaw Creek watershed has a population of 1,100 permanent residents. The maximum population typically occurs during the winter season, with an additional 700 seasonal residents, 19,500 daily visitors and 2,000 employees.

2.1.2 Climate

The climate is typical of high-altitude alpine settings and is characterized by rapidly changing weather conditions and strong microclimate effects. Average annual precipitation within the watershed is approximately 32 inches. Precipitation occurs primarily in the winter months as snow. The long-term average annual snowfall is about 200 inches. At elevations above 7,000 feet, average annual snowfall is about 240 inches (Western Regional Climate Center [WRCC], 2005).

Temperatures are usually mild during the summer months, averaging 75 to 80 degrees Fahrenheit (°F) during the day with lows typically between 35° and 45°F. Winter low temperatures are often in the teens but rarely fall below 0°F (WRCC, 2005).

2.1.3 Geology

The major rock types of the Squaw Creek watershed are Cretaceous granitic rocks, Tertiary volcanics (andesite), and Quaternary glacial tills (Figure 2-2). The granitic rocks are part of the Sierra Nevada batholith. The volcanic units are composed of highly weathered andesitic breccias and mixed pyroclastics and andesitic flows (Birkeland, 1961; Saucedo and Wagner, 1992). The glacial tills were deposited during the Tioga and Tahoe glaciations (Birkeland, 1964). Small outcroppings of metamorphic rocks are found in the north fork subwatershed.

The general distribution of the geologic units of the north fork of the Squaw Creek watershed is approximately 63 percent granitics, 33 percent volcanics, and 3 percent metamorphic rocks (Maholland, 2002). Volcanic units occur along the northern watershed boundary and along the western ridgeline between the north and south forks. The north fork creek is located primarily in granitic terrain.

The general distribution of the geologic units of the south fork of the Squaw Creek watershed is approximately 40 percent granitics, 40 percent volcanics, and 17 percent glacial deposits (Maholland, 2002). The glacial deposits in the south fork are Tioga age tills composed of boulders and cobbles in a fine-grained matrix. The south fork contains less granite and more volcanics and glacial till than the north fork, which may be an important factor in sediment production in the watershed, since volcanic rock and glacially-derived material tend to be more erodible and sensitive to disturbance than granitic material.

The geology of the meadow reach of Squaw Creek consists primarily of glacial till deposits and alluvial fans along the sides of the meadow. Sediments in the valley bottom consists of a mixture of fluvial, lacustrine and colluvial deposits (Birkeland, 1961).

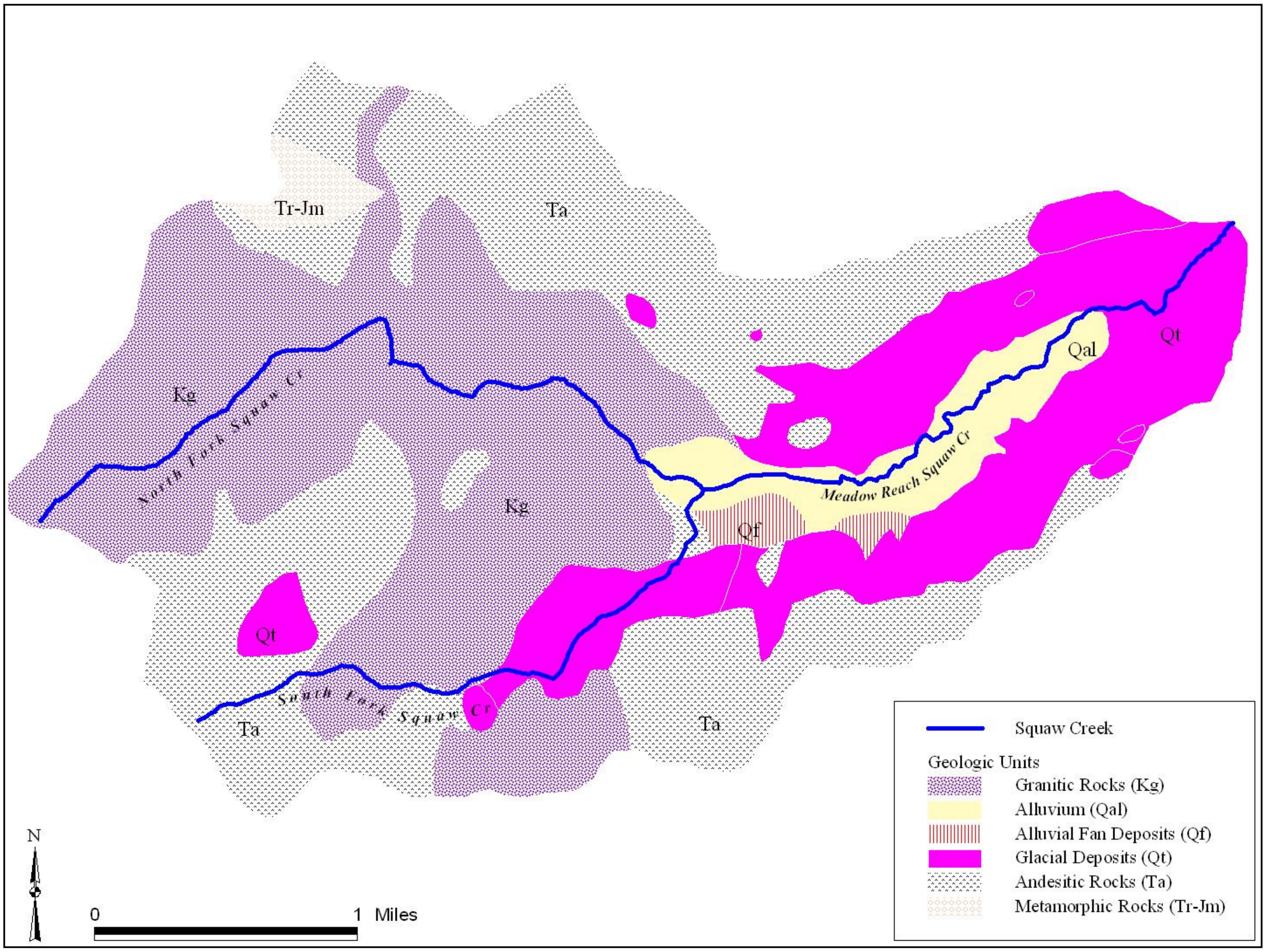
2.1.4 Soils

The USFS - Tahoe National Forest (1994) mapped and classified the majority of the soils in the watershed as having moderate to very high erosion susceptibility. Soil complexes in the Squaw Creek watershed are typically shallow, consisting of rock fragments in a fine-grained matrix. The main soils of the watershed include Aquolls and Borolls on the valley floors and Jorge, Meiss, Tallac, and Waca series on the moderate and steeper slopes.

At elevations above 6,500 feet, soils have formed primarily from weathered granitic and volcanic rocks and include alluvial and glacial deposits. These soils are generally have a high to very high erosion hazard rating (USFS, 1994).

Poorly drained, nutrient rich soils (Aquolls and Borolls) can be found in small, high mountain lake basins (e.g., Shirley Lake area) and the meadow reach of Squaw Creek. These soils are usually well vegetated and less susceptible to erosion by the virtue of their landscape position. Young fluvial deposits, consisting of silts and sands with gravels, cobbles, and boulders are found primarily along the margins of the active channel of Squaw Creek and produce sediment primarily through stream bank erosion processes (Maholland, 2002).

Figure 2-2
Geologic Units of the Squaw Creek Watershed



2.1.5 Geomorphology and Hydrology

As shown on Figure 2-3, the Squaw Creek drainage network can be divided into three major reaches: the north fork of Squaw Creek; the south fork of Squaw Creek; and the meadow reach of Squaw Creek. There are numerous first through third order tributary streams feeding into the main channels. The north and south forks of Squaw Creek reflect the geologic processes, including glacial and volcanic activity, that shaped the Sierra Nevada mountains. Bedrock-dominated, relatively steep channels characterize the north and south fork subwatersheds. The south fork is slightly steeper than the north fork, as indicated by gradients of 0.20 and 0.17, respectively (Maholland, 2002). Both forks flow through armored, trapezoidal-shaped channels for approximately one-quarter mile above their confluence. After the confluence of the two forks, flow in Squaw Creek continues for approximately one half-mile through this channelized section before entering the meadow reach.

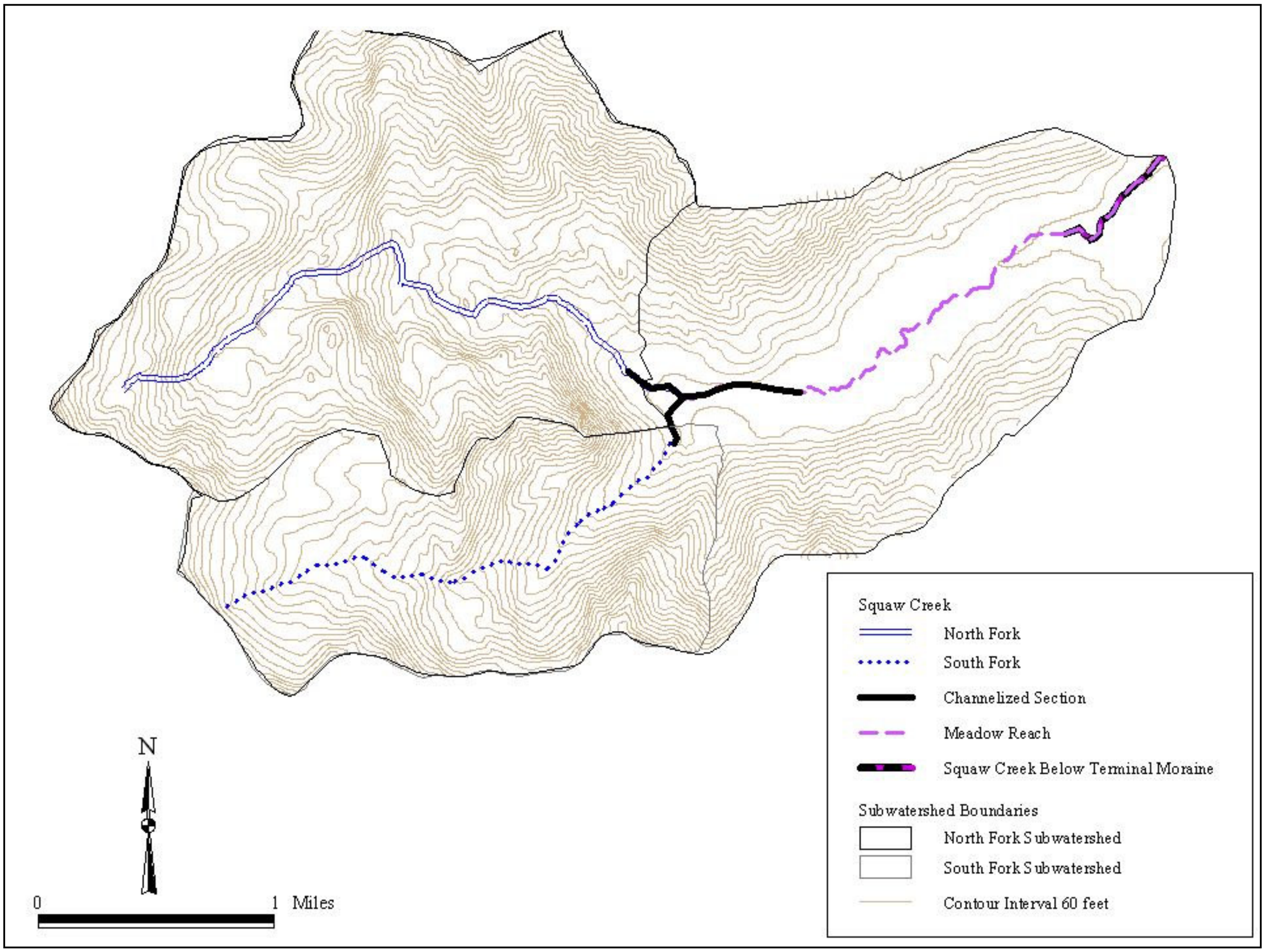
The meadow reach is a meandering alluvial channel with an average gradient less than 0.02. Base flows are often minimal or subsurface through this section during the summer and fall. Sediment deposition within the reach has produced a deep bed of alluvium within which surface water may infiltrate and result in intermittent flows (Herbst, 2002). Many meander bends within the meadow reach have been armored with boulders (rip-rap), and the base level of the reach is maintained by a terminal moraine at the foot (east end) of the meadow. From the terminal moraine to the creek's confluence with the Truckee River, Squaw Creek follows a steeper, stable, boulder-controlled gradient.

Squaw Creek was not gauged to measure flow rate at the time TMDL studies were conducted. Therefore, long-term stream flow and stage characteristics, such as flow duration curves, mean annual discharge, and peak flows, are not well characterized. Surface water hydrology in the watershed is driven largely by snowmelt, which typically has a peak runoff associated with spring snowmelt. Snowpack and rate of melt controls the magnitude of the spring runoff. Significant runoff can occur during intense summer thunderstorms and during rain-on-snow events in the winter and spring.

2.1.6 Biota

Vegetation in the Squaw Creek watershed is largely stratified by elevation, slope, and aspect. It can be divided into lower montane, upper montane, and subalpine vegetation zones. In general, the vegetation is composed of East Side mixed conifer forest (white fir and jeffrey, sugar, and lodgepole pines), red fir forest, subalpine forest (whitebark pine and mountain hemlock), montane and alpine meadow plant communities, montane chapparal (ceanothus species, manzanita, bitterbrush), and wet meadow grasses and riparian vegetation (willow, aspen, dogwood, and alder) (Maholland, 2002). Steep, upper elevation slopes along the Sierra crest support little vegetative cover, and this is typical of the upper watersheds in both forks and along the ridges above the valley.

Figure 2-3
Squaw Creek Stream Reaches and Watershed Topography



A recent search of the California Natural Diversity Database's online database (CDFG, 2005) identified several threatened, endangered or special concern species potentially occurring in the Squaw Creek watershed, shown in Table 2-1:

Table 2-1
Threatened, Endangered, or Special Concern Species in the Squaw Creek Area

Common Name	Scientific Name	Federal Status	State Status	DFG Status	7.5' Quad Name
Mountain yellow-legged frog	Rana muscosa	Endangered	None	Special Concern	Tahoe City, Granite Chief
Willow flycatcher	Empidonax traillii	None	Endangered	None	Tahoe City
Lahontan cutthroat trout	Oncorhynchus clarki henshawi	Threatened	None	None	Tahoe City, Granite Chief
Northern goshawk	Accipiter gentilis	None	None	Special Concern	Tahoe City
Yellow warbler	Dendroica petechia brewsteri	None	Endangered	None	Tahoe City
Sierra Nevada snowshoe hare	Lepus americanus tahoensis	None	None	Special Concern	Tahoe City
Western white-tailed jackrabbit	Lepus townsendii	None	None	Special Concern	Tahoe City
Sierra Nevada mountain beaver	Aplodontia rufa californica	None	None	Special Concern	Tahoe City, Granite Chief
California wolverine	Gulo gulo	None	Threatened	None	Tahoe City
Tahoe yellow cress	Rorippa subumbellata	Candidate	Endangered	None	Tahoe City

The watershed also provides habitat suitable for common species such as red-tailed hawk (*Buteo jamaicensis*), Stellar's jay (*Cyanocitta stelleri*), coyote (*Canis latrans*), black bear (*Ursus americanus*), raccoon (*Procyon lotor)*, and mule deer (*Odocoileus hemionus*), and species of terrestrial and arboreal rodents (Ziener, et.al., 1988).

Documented fish populations include introduced rainbow, brook and brown trout. Native minnows (cyprinids) were sighted during 2002-2003 fish surveys, including speckled dace and Lahontan redside shiners (pers. comm., W. Cowan, USFWS, Nov. 7, 2003). Lahontan cutthroat trout (LCT) are native to the Truckee River basin and were once the only trout throughout the watershed. Although recent surveys found no LCT in Squaw Creek, it is likely that Squaw Creek historically provided habitat for Lahontan cutthroat trout (pers. comm, W. Cowan, USFWS, Nov. 7, 2003). The LCT was federally listed as endangered in 1970 and reclassified as threatened in 1975 to facilitate management and allow regulated angling (USFWS, 1995). Reintroduction of LCT to the mainstem Truckee River is currently underway (USFWS, 2003).

2.2 BENEFICIAL USES OF SQUAW CREEK

Water quality standards include designated beneficial uses of water and narrative and numerical water quality objectives established to protect those uses. Chapter 2 of the Basin Plan contains definitions of the beneficial uses assigned to waters in the Lahontan Region. The designated beneficial uses of Squaw Creek are:

- Municipal and Domestic Supply (MUN)
- Agricultural Supply (AGR)
- Groundwater Recharge (GWR)
- Water Contact Recreation (REC-1)
- Non-Contact Water Recreation (REC-2)
- Commercial and Sportfishing (COMM)
- Cold Freshwater Habitat (COLD)
- Wildlife Habitat (WILD)
- Rare and Endangered Species Habitat (RARE)
- Migration of Aquatic Organisms (MIGR)
- Spawning, Reproduction and Development (SPWN)
- Water Quality Enhancement (WQE)
- Flood Peak Attenuation/Flood Water Storage (FLD)

2.3 APPLICABLE WATER QUALITY OBJECTIVES

Sediment-related water quality objectives established in the Basin Plan are listed in Table 2-2. The majority of sediment-related water quality objectives are expressed in narrative form based on the protection of beneficial uses.

Table 2-2
Sediment-Related Water Quality Objectives Contained in the Basin Plan

Objective	Description
Sediment	The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect the water for beneficial uses.
Suspended Materials	Waters shall not contain suspended materials in concentrations that cause nuisance or that adversely affect the water for beneficial uses. For natural high quality waters, the concentration of total suspended materials shall not be discernible at the 10 percent significant level.
Settleable Materials	Waters shall not contain substances in concentrations that result in deposition of material that causes nuisance or that adversely affects the water for beneficial uses. For natural high quality waters, the concentration of settleable materials shall not be raised by more than 0.1 milliliter per liter.

Objective	Description
Turbidity	Truckee River Hydrologic Unit: The turbidity shall not be raised above 3 Nephelometric Turbidity Units (NTUs), mean of monthly means. Lahontan Region-wide: Waters shall be free of changes in turbidity that cause nuisance or adversely affect the water for beneficial uses. Increases in turbidity shall not exceed natural levels by more than 10 percent.
Nondegradation	Whenever the existing quality of water is better than the quality of water established in the Basin Plan as objectives (numeric or narrative), such existing quality shall be maintained unless appropriate finding are made under Resolution No. 68-16 "Statement of Policy with Respect to Maintaining High Quality Waters of California."

2.4 IMPAIRMENT OF BENEFICIAL USES

2.4.1 General Excessive Sedimentation Effects

Fluvial environments are conveyance systems for water and sediment produced in a watershed. Sediment is an important, naturally occurring component of healthy streams and rivers that benefits many elements of the biologic community. However, an excessive amount of sediment in streams can have adverse effects on the in-stream biologic communities and recreational and municipal uses.

Waters (1995) provides a comprehensive literature review of the impacts of suspended and deposited sediment on in-stream beneficial uses. These impacts include coating of "biologically active surfaces" of plants and animals (e.g., fish gills), abrasion and suffocation of attached algae, reduction of light for photosynthesis, and modification of animal behavior and benthic invertebrate habitat.

Suspended sediment may have sub-lethal effects on fish, including reduced feeding and growth, respiratory impairment, and physiological stress leading to reduced tolerance to disease and toxicants. Deposited sediment can have significant impacts on the reproductive success of salmonid fish by filling interstitial spaces in spawning gravels, reducing water and oxygen flow to fish embryos and fry, smothering of embryos and fry, and entrapment of emerging fry (Waters, 1995). High rates of sediment transport can initiate scour and fill of the bed, removing embryos or burying them deeply. Volcanic rocks produce greater percentages of soils containing silt and fine sand than granitic rocks and these materials are likely to penetrate deeper into a gravel bed, thus increasing the negative effects on fish spawning success (Lisle and Eads, 1991).

Changes to channel form and velocity distribution (e.g., pools and riffles) resulting from increased sediment deposition can limit the migration and movement of aquatic organisms. Excessive sedimentation, turbidity, and undesirable substrate material can adversely impact swimming, wading, fishing and aesthetic enjoyment of streams. Excess sediment loading can also foul water treatment and supply facilities, which increases operational costs and affects service.

2.4.2 Squaw Creek 303(d) Listing Basis

The Regional Board identified Squaw Creek as impaired by excessive sedimentation, and the creek was placed on the 303(d) list in 1992. Data supporting the listing included a study on sediment transport in Squaw Creek that described elevated sediment levels in the creek (Woyshner and Hecht, 1987). Woyshner and Hecht reported that bedload transport rates in Squaw Creek during 1986 (when precipitation was 150 percent of the long-term average) were six to seven times greater than those reported for nearby Sagehen Creek in 1983, when springtime snowmelt runoff had the largest period of sustained high flows that had occurred in the preceding 30 years. Sagehen Creek's annual average stream flow was 55 percent greater in 1983 than it was in 1986, when Squaw Creek's bedload was measured. Though the bedload measurements are not directly comparable, Woyshner and Hecht's assessment does indicate Squaw Creek's bedload sediment transport is significantly greater than a nearby creek that is similar to Squaw Creek in geology, relief, and meadow presence, though with about twice the watershed area as Squaw Creek.

Further information related to the sediment listing was provided in a 1990 California Department of Fish and Game (CDFG) memo (Messersmith, 1990), which listed siltation and loss of fish habitat as problems in Squaw Creek. Additionally, complaints related to sediment discharges have been lodged with the Regional Board, and there have been sediment-related violations of permit conditions and waste discharge prohibitions.

2.4.3 Squaw Creek Beneficial Use Impairment

Because erosion is a natural process and some sedimentation is needed to maintain healthy stream systems, a necessary step in developing a sediment TMDL is to evaluate the degree to which erosion and sedimentation in a particular watershed exceeds natural patterns, and how that may effect beneficial uses. To assist in that evaluation, part of the approach used in this TMDL included biological assessment (bioassessment) using the "reference stream" method (USEPA, 1999) described below.

Biological health can be assessed by examining the number, diversity and types of bottom dwelling aquatic organisms (benthic invertebrates such as worms and immature forms of insects) living in the substrates of regional streams. By sampling physically comparable streams with a range of human-caused disturbance levels, a desired ("reference") biologic condition, represented by the minimally disturbed sites (referred to as "reference" streams), can be determined for the region. The biological health and physical habitat attributes of streams in watersheds with higher levels of development can be assessed according to that benchmark.

Data from the bioassessment studies commissioned for the Squaw Creek TMDL indicate that the narrative water quality objectives for sediment and settleable materials are not fully met, contributing to the impairment of at least the COLD, SPWN, REC-1, REC-2, WILD, MIGR, and COMM beneficial uses. Further discussion supporting this determination is presented below.

In-Stream Conditions

In-stream effects of sedimentation on aquatic life beneficial uses were assessed in terms of physical habitat and the biologic communities present in reference streams compared with conditions in Squaw Creek. This comparison was done through bioassessment studies completed by Dr. David Herbst of University of California's Sierra Nevada Aquatic Research Laboratory (SNARL).

Six sites were sampled in the Squaw Creek watershed from the upper to lower portions of the drainage basin. These sites were divided into three stream types based on location and geomorphology: 1) two upper watershed sites representing higher gradient first to second order stream types; 2) three low gradient mid-watershed sites representing second to fourth order stream types); and (3) one lower watershed site located below the terminal moraine, just above the Truckee River. Selection of reference sites corresponding to each of the three Squaw Creek stream types was based on similarity with regard to the following criteria:

- stream order (±1)
- channel width (±100-300 cm)
- size/length of upstream watershed (some similar size, others ± 0.25-3 times length)
- elevation (mostly within 6,000–7,000 foot zone)
- gradient (±2% in most cases)
- aspect (eastern orientation)
- geographic proximity (within 20 mile radius, and tributary to Truckee River)
- geologic and geomorphic setting

A complete discussion of the SNARL biologic assessment study completed for this TMDL is included in Appendix B.

Due to the steep gradient in the western portion of the watershed, the north and south forks appear to function as sediment transport reaches that convey sediment to the meadow reach, where the low-gradient channel provides a depositional zone. Therefore, the in-stream effects of sedimentation are apparent primarily in the meadow reach. Based on comparisons of physical habitat data, the stream channel in the meadow reach contains more fine sediment than other low gradient stream reaches located in watersheds with less land disturbance (reference streams). Additionally, benthic macroinvertebrate communities in the meadow reach indicate impaired conditions for aquatic life compared with those found in reference streams.

The SNARL bioassessment studies were conducted over a two-year period (2000–2001) when stream flows in Squaw Creek varied more between sampling years when compared to reference streams. For example, during the first year of bioassessment sampling, flows in the meadow reach of Squaw Creek were so low that they could not be measured using a flow-meter. Lack of flow not only limits the availability of suitable habitat for benthic invertebrates, it also influences the fluvial processes that control in-stream sediment transport and deposition, further contributing to impairment of aquatic life beneficial uses. While the bioassessment studies indicate that aquatic organisms in the meadow reach and in the South Fork are adversely affected by excess sediment delivery to the creek, they also suggest that low flow conditions in the meadow reach may also adversely affect aquatic organisms.

Several key watershed conditions influence the Squaw Creek's flow regimes. Land disturbance in the higher-gradient, upper watershed accelerates runoff, reduces infiltration, and decreases subsurface storage, which can cause flows in the creek system to dissipate earlier in the season. Land uses and stream channel modifications may also contribute to stream channel incision, which can lower the water table in the meadow and inhibit over-bank flow events that help attenuate seasonal flow fluctuations. The groundwater aquifer in the Squaw Creek meadow area is the source of municipal water supplies for Squaw Valley, and studies to assess stream flow reductions associated with the groundwater pumping are ongoing. Flow concerns associated with groundwater pumping are outside the scope of this sediment TMDL; however, these concerns have been communicated to staff of the State Board Water Resources Control Board, Division of Water Rights.

Physical Habitat Conditions

During 2000-2001 SNARL bioassessment studies, sediment-related stream data were collected from Squaw Creek TMDL sites and reference stream sites to correlate modeled sediment load estimates to in-stream measures of sediment deposition and biologic community observations. Squaw Creek meadow TMDL sites showed smaller median particle size and larger average percentages of fines and sand when compared to low gradient reference stream sites such as Perazzo Creek, Cold Creek, Independence Creek and the Little Truckee River (Herbst, 2002). Particle size distribution is an important indicator of habitat suitability for aquatic life. Excessive fine particles deposited on the streambed can be detrimental to fish and invertebrates by increasing embeddedness of gravels and decreasing interstitial spaces, leading to changes in species composition and diversity (Waters, 1995). Clean cobbles and gravels are needed to provide suitable spawning conditions and habitat diversity.

SNARL's sampling results indicate that, on average, 38 percent of the Squaw Creek meadow reach substrate is composed of fines and sand, while reference site conditions generally show levels less than 25 percent. Median particle size (D-50) values for the meadow reach of Squaw Creek averaged 18 millimeters; data from comparable reference sites shows values of 40 millimeters or greater. These data indicate that the Squaw Creek channel substrate has increased fine sediment and decreased interstitial space compared to the reference sites, indicative of less desirable habitat for aquatic life.

Benthic Macroinvertebrates

Benthic macroinvertebrates are aquatic organisms at least a half-millimeter in size that live on stream or lake substrates for at least some part of their life. They include aquatic worms and the immature forms of aquatic insects such as stonefly and mayfly nymphs. They are commonly used to assess water quality, because they act as continuous monitors of the water they inhabit, enabling long-term analysis of both regular and intermittent discharges, variable concentration of pollutants, single or multiple pollutants, and even synergistic or antagonistic effects (Harrington and Born, 2000). They are also an important part of the food chain, providing a valuable nutrient source for fish.

A variety of stream sites were assessed in the middle Truckee River basin by SNARL to support Squaw Creek TMDL development. The goals of the bioassessment study were to: 1) describe the existing condition of biological health in Squaw Creek, 2) compare conditions in Squaw Creek to reference watershed streams and, 3) examine the relationship between sediment load and biological integrity. A total of 28 stream sampling sites at 22 separate stream locations (six sites were sampled twice) were assessed during 2000 and 2001.

The stream sites sampled during the study are referred to follows:

- TMDL sites – Six sites sampled in the Squaw Creek watershed;
- Reference sites – Sites physically comparable to Squaw Creek reaches, with conditions associated with relatively undisturbed landscapes. All sites are tributaries to the middle Truckee River; and
- Load Exposure sites - Physically comparable stream sites on Trout and Alder Creeks that have relatively more disturbance in their respective watersheds than the reference sites. Load exposure sites were included in the study to evaluate the biologic response to sedimentation along a gradient of conditions (USEPA, 1999; Karr and Chu, 1999)

The six TMDL sites in the Squaw Creek watershed were selected to represent the three major stream types exhibited by the creek: high gradient stream reaches (north and south fork sampling sites), low gradient stream sites (upper, middle, and lower meadow sites), and a lower watershed stream site (below moraine site). Figure 2-4 shows the locations of the Squaw Creek bioassessment study sites. Reference stream sites and load exposure sites were also sampled based on their similarity to the characteristics exhibited by the three types of Squaw Creek TMDL sites. Figure 2-5 shows the locations of the reference and load exposure stream sites.

Figure 2-4
Squaw Creek Bioassessment TMDL Sites

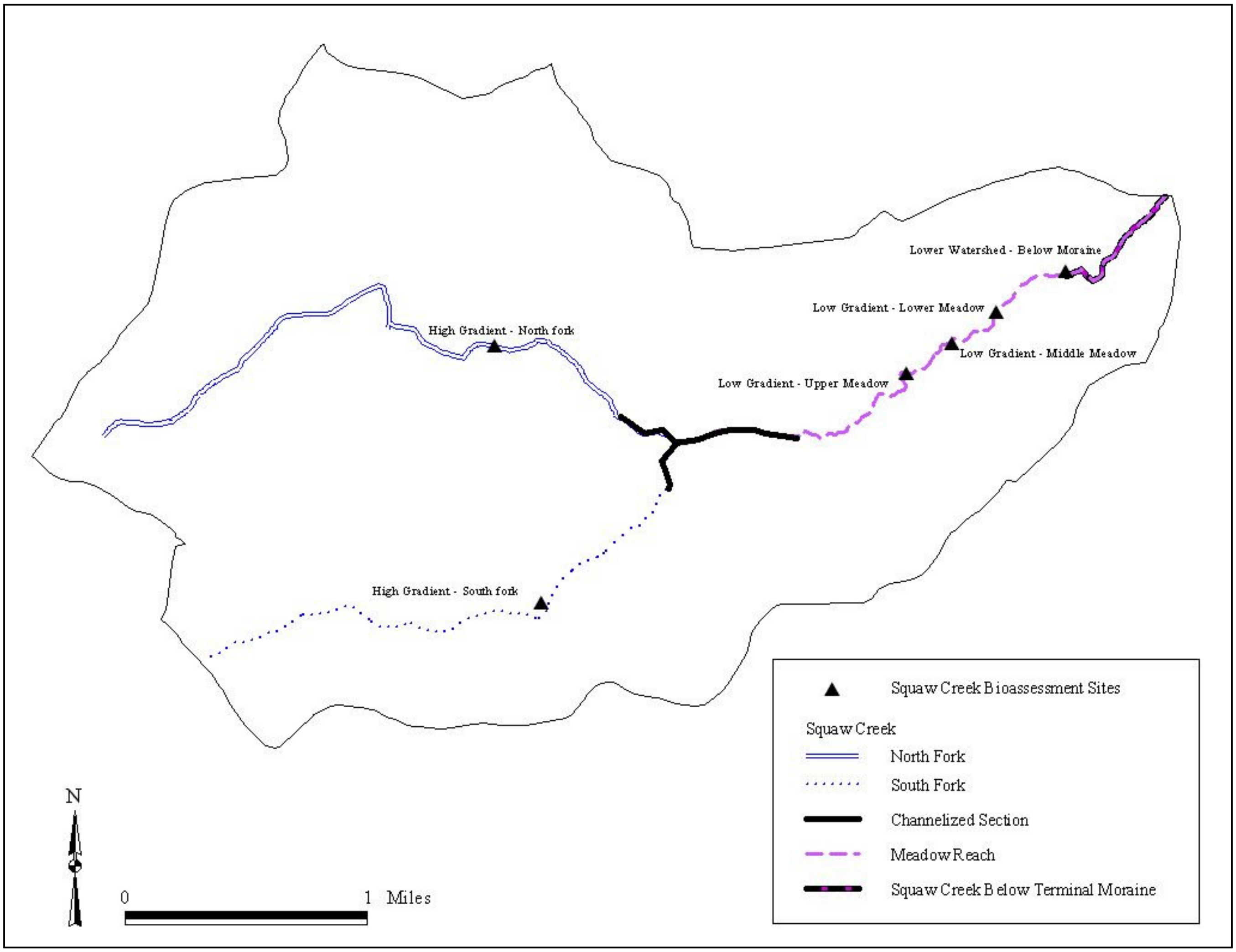
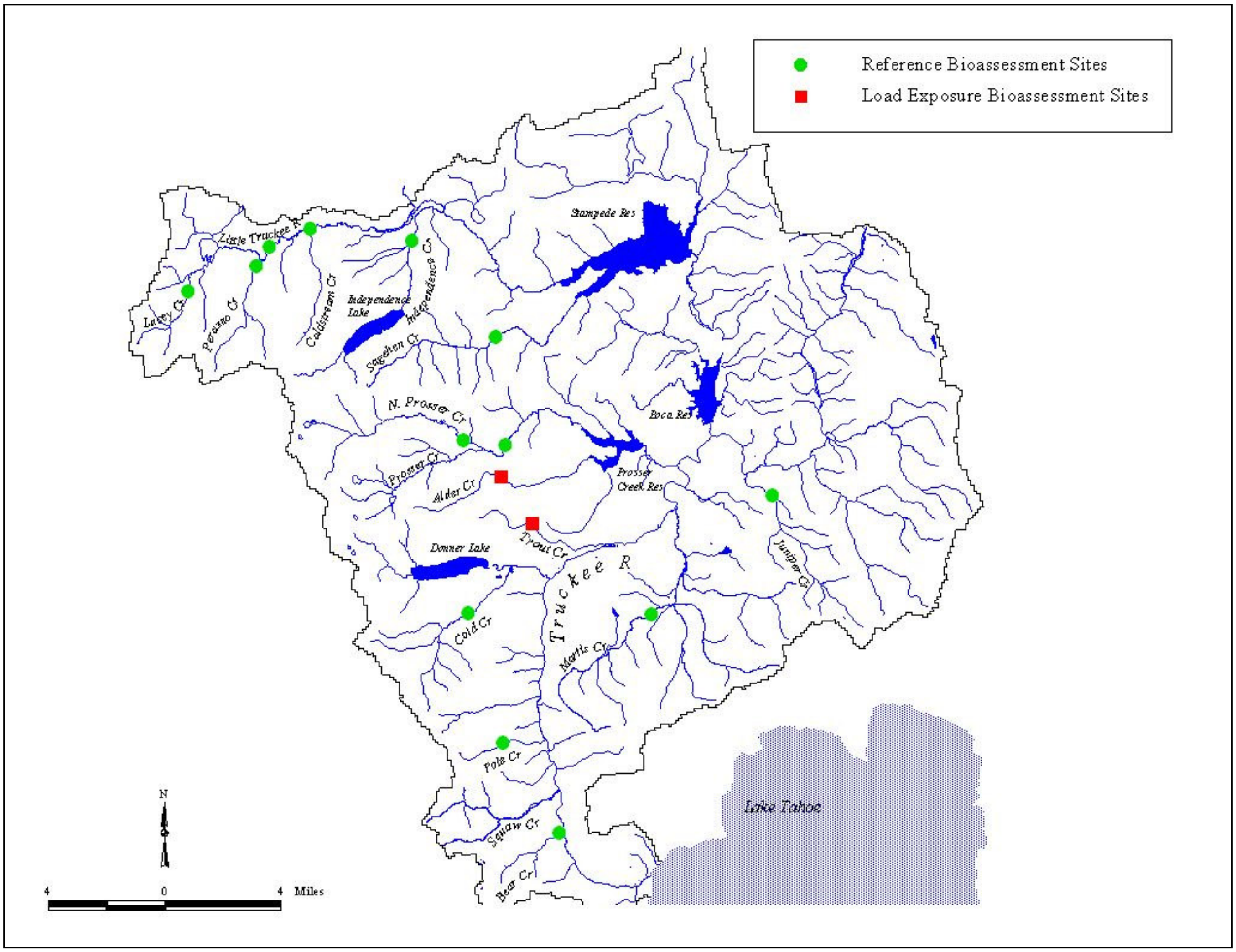


Figure 2-5
Reference and Load Exposure Bioassessment Sites



Bioassessment data were consolidated into a single indicator, called a biologic condition score, which was used to compare conditions in Squaw Creek sites to the reference stream sites.

A summary of the biologic condition scores for Squaw Creek's meadow reach and low gradient reference sites is presented in Table 2-3. Average biologic conditions scores for the meadow reach in 2000 were 70 percent lower than the average score for other low gradient reference sites. However, flows were noted to be discontinuous in 2000 and samples were collected at the head or tail of pools because no riffle habitat was present. Biologic condition scores for the Squaw Creek TMDL meadow reach site showed 100 percent improvement in 2001 when flows were continuous, but were still below the average score for the low gradient reference sites by approximately 25 percent.

Table 2-3
Comparison of Squaw Creek Meadow Reach Biologic Condition Scores to Low Gradient Reference Stream Sites

Site	Biologic Condition Score
Squaw Creek upper meadow – 2000	9
Squaw Creek middle meadow – 2000	9
Squaw Creek lower meadow – 2000	11
2000 Squaw Creek Low Gradient Average	**10** **(number of sites [n]=3)**
2000 Low Gradient Reference Site Average	**32** **(n=4)**
Squaw Creek upper meadow – 2001	Not Sampled
Squaw Creek middle meadow – 2001	23
Squaw Creek lower meadow – 2001	17
2001 Squaw Creek Low Gradient Average	**20** **(n=2)**
2001 Low Gradient Reference Site Average	**27** **(n=6)**

The scores for the high gradient and lower watershed stream types are summarized in Table 2-4. Biologic condition scores for the high gradient Squaw Creek TMDL sites (located on the north and south forks) show that the average scores for those sites are comparable to the average scores for the reference sites. Biologic condition scores for the lower watershed stream site (Squaw Creek below moraine) were also comparable to the reference scores. This suggests that the upper and lower Squaw Creek watersheds are not significantly impacted by sediment and that the primary impacts are to the meadow reach. This may be attributable to sediment load movement through the system in the higher gradient upper watersheds, and sediment deposition in the low gradient meadow reach above the lower watershed (below moraine) site (Herbst, 2002).

Table 2-4
Comparison of Squaw Creek TMDL and Reference Sites Biological Condition Scores (BCS) - High Gradient and Lower Watershed Stream Type Sites

Site	2000 BCS	2001 BCS	2-Year Average BCS
South Fork – High Gradient Site	21 (n=1)	29 (n=1)	25 (n=2)
North Fork – High Gradient Site	31 (n=1)	33 (n=1)	32 (n=2)
High Gradient Reference	**31 (n=1)**	**29 (n=2)**	**30 (n=3)**
Below Moraine – Lower Watershed Site	29 (n=1)	Not sampled	29 (n=1)
Lower Watershed Reference	**32 (n=2)**	**29 (n=1)**	**31 (n=3)**

Fisheries

The Squaw Creek fishery has not been extensively evaluated; however, there are limited studies and anecdotal information collected from local residents and resource agency staff that supplement the determination that aquatic life beneficial uses are impaired due to both sedimentation and low flow conditions.

Historically, a state-operated fish hatchery was located on Squaw Creek from 1875 to 1880 (Leitritz, 1970) and eastern brook trout were planted between 1950 and 1954 (pers. comm., Quinones, CDFG, Dec., 2003). In 1972, CDFG reported an average resident population of 50 pounds of trout per acre in Squaw Creek (JARA, 1974), while a stream survey conducted by the USFS in 1973 noted an average of six to ten trout per 100 feet in the meadow reach of Squaw Creek (USFS – Tahoe National Forest, 1973). Both brown and rainbow trout were present in about equal numbers.

Snorkel surveys conducted in 2002 and 2003 by the U.S. Fish and Wildlife Service (USFWS) found rainbow trout, brown trout and brook trout in various reaches of Squaw Creek. Brook trout were present in the upper reaches of the north fork, while the rainbow and brown trout were in the lower gradient, lower elevation meadow and confluence areas. The survey found that brown trout outnumbered rainbow trout by about 20 to 1 (pers. comm., W. Cowan, USFWS, Nov., 2003), indicating that the current flow/sediment regime and habitat conditions may be favoring brown trout. Brown trout adapt more easily to a wide variety of habitat conditions (NCSU, 2005). Additionally, rainbow trout may be particularly stressed by the lack of late summer water. Because rainbow trout spawn in the spring, their fry emerge during the summer and are likely most affected by dry summer stream conditions, while brown trout spawn in fall, and their fry emerge during the higher flow winter months. While both species are negatively affected by excess sediment, it is possible that increases in sediment transport during spring runoff along with the timing of scour and sediment deposition affect rainbow trout more than brown trout. In addition to providing habitat for resident trout, Squaw Creek provides spawning habitat for trout residing in the Truckee River.

Wildlife surveys conducted between 1981 and 1983 by Drs. Albert J. Beck and Roger J. Lederer found the in-stream habitat conditions of Squaw Creek to be affected by turbidity, sedimentation and stormwater pollutants. There were few areas of abundant cobbles or spawning gravel, and little riparian cover (Resort at Squaw Creek, 1984). During the environmental review period for the development of the Resort at Squaw Creek, a longtime local resident commented that the fisheries and wildlife in the meadow environment have steadily declined since 1955, due particularly to the effects of channelization of Squaw Creek's western end and siltation and pollutants from parking lots and the ski area (Poulsen, 1984).

Another longtime local resident began taking field notes in 1992 when he first noticed dead trout appearing in the creek. According to his records, the meadow and/or channelized sections of Squaw Creek have dried during late summer or early fall of 1992, 1994, 2001, 2002, and 2003, leaving up to 100 trout per year stranded and dying (pers. comm, C. Gustavson, Sept. 29, 2003). The 2002 USFWS survey coincided with a dry year, and field staff found many pools with stranded fish during the 2002 survey. In 2003, several age classes of trout, including young-of-year, were observed, indicating that while many trout die, some manage to survive the low flow conditions.

Hillslope Conditions

As a result of various land use and development activities, natural vegetation has been removed from hillslopes in areas of the south fork of Squaw Creek, and to a lesser extent in the north fork (JARA, 1975; Culver and LSA Associates, 1995; Save Shirley Canyon Committee, 1986). Land disturbance also has occurred on the hillsides to the north and south above the meadow reach of Squaw Creek. Construction of ski runs, dirt roads, residential and commercial areas, and other impervious surfaces tend to increase erosion in the watershed, while drainage features associated with roads and parking areas concentrate runoff and increase the rate of sediment loading to surface waters. Additionally, maintenance activities such as dirt road grading and winter road sanding also contribute to anthropogenic sediment discharges. Examples of the effects of land disturbance in the watershed are shown in pictures taken during a 1999 field inspection and are presented in Appendix A.

The modification of natural drainage patterns in a watershed can have significant affects in increasing the rate of sediment loading to surface waters. Drainage patterns can be expressed by a watershed's drainage density, defined as the average length of streams per unit area. The drainage density indicates the relative distance overland flow on hillslopes must travel to reach stream channels (Maholland, 2002). According to Wemple et al. (1996) and Jones et al. (2000), the overall drainage density of a watershed is increased via road network connectivity with the stream network because roads function as extensions of the drainage network. Factoring in the dirt road network alone increases the effective drainage density in Squaw Creek's south fork watershed approximately 250 percent, and in the north fork watershed, by about 10 percent. The increase in effective drainage density means that the length of runoff distance from hillslopes to streams is reduced and sediment from hillslopes is transported more rapidly to streams.

Road density is frequently used as an overall indicator of the impacts of roads in a watershed because of the negative effects associated with increased density (e.g., disruption of natural drainage and sediment storage patterns, higher runoff, increased sediment delivery to streams). The Squaw Creek watershed had a particularly high density of road in certain portions of the watershed. The dirt road density of the entire watershed is 5.8 miles per square mile (mi/mi^2), with the highest density occurring in the south fork subbasin: 16.2 mi/mi^2 (Maholland, 2002). Increased peak flow in streams may be evident at road densities of 3-5 mi/mi^2 (Foreman and Alexander in Maholland, 2002).

Poorly managed hillslope conditions and construction practices contributing to excess sedimentation in Squaw Creek are described in a Regional Board Cleanup and Abatement Order (CAO) issued to SVSC in 2001 (Board Order R6-2001-0074). The CAO requires actions to address conditions at Squaw Valley USA Ski Area (SVSA) that led to violations of waste discharge requirements and Basin Plan prohibitions. The violations pertained to certain operations and development activities that resulted in unauthorized soil disturbance and waste discharges to surface waters, as well as failure to maintain or implement adequate best management practices (BMPs) to control erosion and sedimentation. These conditions caused additional sediment discharges into Squaw Creek and its tributaries (Lahontan RWQCB, 2001).

3. NUMERIC TARGETS

The CWA Section 303(d)(1)(C) states that TMDLs "… shall be established at a level necessary to implement the applicable water quality standards." Water quality standards include the designated beneficial uses of waters and the water quality objectives established to protect beneficial uses. Because the applicable water quality objectives for this TMDL are narrative, rather than numeric, indicators and associated target values were developed to assess attainment of narrative sediment-related water quality objectives and ensure protection of aquatic life beneficial uses.

Indicators and target values representing desired conditions for physical habitat and biologic health in Squaw Creek were selected from an array of parameters measured during the 2000–2001 SNARL bioassessment work discussed in the previous section. The targets apply to the meadow reach of Squaw Creek because it appears to be the most sensitive to sedimentation due to its watershed position and geomorphic characteristics. This is consistent with EPA's Sediment TMDL guidance (1999), which states that "indicators should be sensitive to geographical and temporal issues; they should be placed or located where impacts occur." Because the meadow appears to be the most sensitive to impacts from excessive sedimentation, Regional Board staff believes that meeting the targets in the meadow reach will result in adequate protection of beneficial uses throughout the watershed. Appendix B contains a detailed discussion of bioassessment concepts, sampling location selection, and additional information on numeric target development.

3.1 NUMERIC TARGET DEVELOPMENT

Numeric targets were developed for Squaw Creek based on bioassessment work conducted throughout the Truckee River watershed in 2000 and 2001 by SNARL. Bioassessment is the evaluation of an ecosystem using integrated measurements of habitat and biologic communities in comparison to empirically defined reference conditions (USEPA, 1999). The SNARL bioassessment report (Herbst, 2002) recommended biologic numeric targets for Squaw Creek (a "biologic condition score") and indicators of physical habitat suitability based on a regional comparison of data collected on these characteristics from Squaw Creek and reference sites.

To develop the target values, a variety of physical, chemical, and biological parameters from 28 stream sites in the Truckee River watershed (including Squaw Creek) were measured. A correlation analysis was performed to evaluate the relationship of sediment-related physical variables and biologic community measures to predicted sediment loads obtained from Geographic Information System (GIS) analysis of Annual Agricultural Nonpoint Source (AnnAGNPS, USDA 2000) modeling results. Stream sites that showed minimal watershed disturbance and modeled sediment loads in the lower range for the region were selected *a priori* as reference streams (Herbst, 2002). Two sediment "load exposure" sites (those where sediment loading and land disturbance was predicted to be higher based on AnnAGNPS modeling results) were also selected to provide information on local biologic responses to a gradient of sediment loading exposures, as recommended by USEPA (1999b).

Two physical habitat measures (D-50 particle size and percent fines and sand) showed correlation (R>0.5) to the predicted load and biologic measures and were selected as appropriate physical habitat indicators. The correlation matrix is shown in Appendix B, Table B-2. The target values for these in-stream physical habitat indicators were derived from the range of values observed in the reference streams, and represent desired substrate conditions to protect aquatic life beneficial uses.

Fourteen measures of benthic macroinvertebrate community structure, referred to as "metrics," were analyzed at each stream site. Metrics are attributes that show an empirical and predictable change in value along a gradient of human disturbance. The gradient of human disturbance may be represented by the amount of logging, agriculture, development, impervious surfaces, or other land use or activity in a watershed. An example of a metric is *taxa richness,* which indicates aquatic resource variety measured by the number or richness of taxa (organism groups such as species, genera, or families) found in a sample. Those metrics that correlated with the sediment-related physical habitat parameters described above were selected as indicators of biologic community health for regional streams (see Appendix B for metric descriptions). The seven metrics selected represent measures of the richness, composition and pollution tolerance of the local biologic communities (USEPA, 1999b). They include the following:

- Hilsenhoff Biotic Index
- Mean Taxa Richness
- Ephemeroptera, Plecoptera, Trichoptera (EPT) Diversity Index
- Percent EPT Taxa
- Number Sensitive Taxa
- Percent Tolerant Taxa
- R-50 Index

Metric data collected from each stream site were sorted in ascending order to examine the rank-order distribution of <u>all</u> data points (TMDL, load exposure or reference) for each metric. Breaks in the data distribution were estimated visually and used to segregate measured metric values into standardized scores of five, three, or one. Each site's metric values were then scored according to this system, and the seven individual scores obtained (representing the seven metrics bulleted above) were summed in order to produce a composite biologic condition score for each site. These scores allow direct comparisons to be made among sites. Determining the degree to which a site is impaired is accomplished by comparing its biologic condition scores to those scores obtained in the reference sites; a higher biologic condition score represents better biologic conditions. This allows for future trends in biologic health to be evaluated in a consistent manner, and forms the basis for the numeric target for the biologic health indicator. This approach for biologic target development is consistent with that recommended by USEPA (1996, 1999b).

The numeric targets developed for the Squaw Creek TMDL are summarized in Table 3-1 and discussed in more detail in the following text.

Table 3-1
Indicators and Targets for Squaw Creek TMDL

Indicator	Target Value	Notes	Reference
Physical Habitat: D-50 Particle Size	Increasing trend in D-50 value approaching 40 millimeters (mm) or greater.	Represents desired substrate conditions for aquatic life. Target value based on regional reference stream substrate conditions.	Herbst, 2002
Physical Habitat: Percent Fines and Sand	Decreasing trend in percent fines and sand value approaching 25% cover of the stream bottom or less.	Represents desired substrate conditions for aquatic life. Target value based on regional reference stream substrate conditions.	Herbst, 2002
Biologic Health: Biological Condition Score, calculated from Index of Biologic Integrity (See Appendix B for more details).	Biologic condition score of 25 or more when flows are continuous.	Represents desired biologic integrity of stream, protective of aquatic life uses. Target value equals 23rd percentile of regional reference stream biologic condition scores.	Herbst, 2002

3.1.1 Physical Habitat Numeric Targets

D-50 Particle Size

Discussion

D-50 particle size is a statistical measure of the central tendency of the particle size distribution of the stream channel substrate. For example, a D-50 of 30 means that 50 percent of the stream's substrate is composed of particles greater than 30 millimeters (mm) in diameter, and 50 percent is less than 30 mm. As coarser substrate particles become more abundant, the D-50 values increase.

Particle size distribution is an important indicator of habitat suitability for aquatic life. Excessive fine particles deposited on the streambed can be detrimental to fish and invertebrates by increasing embeddedness of gravels and decreasing interstitial spaces, leading to changes in species composition and diversity (Waters, 1995). Clean cobbles and gravels are needed to provide suitable spawning conditions and habitat diversity. Conditions in low gradient reference streams showed D-50 values generally equal to or greater than 40 mm; therefore, 40 mm is selected as the target to represent satisfactory conditions for aquatic life support. This indicator relates to the COLD, SPWN, and COMM beneficial uses.

Numeric target

- Increasing trend in D-50 value approaching at least 40 mm (geometric mean) in the meadow reach.

Comparison of numeric target and existing conditions

Table 3-2 shows the D-50 particle sizes measured in the meadow reach during 2000 and 2001 stream surveys (Herbst, 2002).

Table 3-2
D-50 Particle Size for Squaw Creek, 2000 - 2001

Year	Squaw Ck Upper Meadow (mm)	Squaw Creek Middle Meadow (mm)	Squaw Creek Lower Meadow (mm)
2000	9.6	18	35
2001	Not measured	4	23

D-50 values represent long-term particle size trends that respond to the complex interaction between sediment delivery to the stream and flow-related fluvial processes. Regional Board staff recognizes that considerable variability exists in this limited dataset. Therefore, drawing definitive conclusions regarding where these data fall in comparison to the target over short time intervals may not be meaningful. However, it is clear that improvement in stream conditions is needed to provide suitable habitat for aquatic life. Due to uncertainties in response time between upland erosion and in-stream physical habitat, D-50 values may take years to respond to erosion mitigation. To account for this uncertainty and variability, the numeric target is expressed as an increasing trend approaching the reference value. Estimated timeframes for TMDL numeric target attainment are discussed further in Section 9.4.

Percent fines and sand

Discussion
For the purpose of this TMDL, fines are defined as mineral substrate less than 1 mm in diameter, and sand is mineral substrate from 1 to 3 mm. As presented in the discussion for the D-50 target, both the amount and size of fine and coarse particles impact aquatic life. Channel substrates in reference streams showed fines and sand values of generally less than 25 percent; therefore, this value was selected as the target to represent satisfactory conditions for aquatic life support. This indicator relates to the COLD, SPWN, and COMM beneficial uses.

Numeric target
- Decreasing trend in percent fines and sand approaching 25 percent within the meadow reach.

Comparison of numeric target and existing conditions:
Table 3-3 lists the percent fines and sand data collected in the Squaw Creek meadow reach during 2000 and 2001 stream surveys (Herbst, 2002).

Table 3-3
Percent Fines and Sand for Squaw Creek, 2000 - 2001

Year	Squaw Ck Upper Meadow (%)	Squaw Ck Middle Meadow (%)	Squaw Ck Lower Meadow (%)
2000	45.3	40	29.3
2001	Not measured	49.3	26.7

The percent fines and sand values represent long-term particle size trends that respond to the interaction between sediment delivery to the stream and flow-related fluvial processes. Therefore, drawing definitive conclusions regarding where these data fall in comparison to the target over short time intervals may not be meaningful; however, the data suggest that improvement in substrate conditions is needed. Due to uncertainties in response time between upland erosion and in-stream impacts, any measure of in-stream physical habitat may take many years to respond to erosion mitigation. To account for this uncertainty, the numeric target is expressed as an increasing trend approaching the reference value. Estimated timeframes for TMDL numeric attainment are discussed further in Section 9.4.

3.1.2 BIOLOGIC HEALTH NUMERIC TARGET

Biologic Condition Score

Discussion
The biologic condition score is a numeric value based on an index of seven biologic metrics that are sensitive to changes in biological integrity caused by sedimentation, as discussed previously in this section. The assessment of the biologic condition of aquatic communities is important to determine how well a water body supports aquatic life (USEPA, 2002).

Numeric target

- Biological condition score of 25 or greater in the meadow reach when flow is continuous. The target shall be evaluated as a rolling average of three consecutive sampling events conducted once every two years. The numeric value of 25 corresponds to the 23rd percentile of low gradient reference site scores; therefore, it represents reasonably achievable desired conditions for benthic aquatic life that are protective of beneficial uses related to COLD, SPWN and COMM.

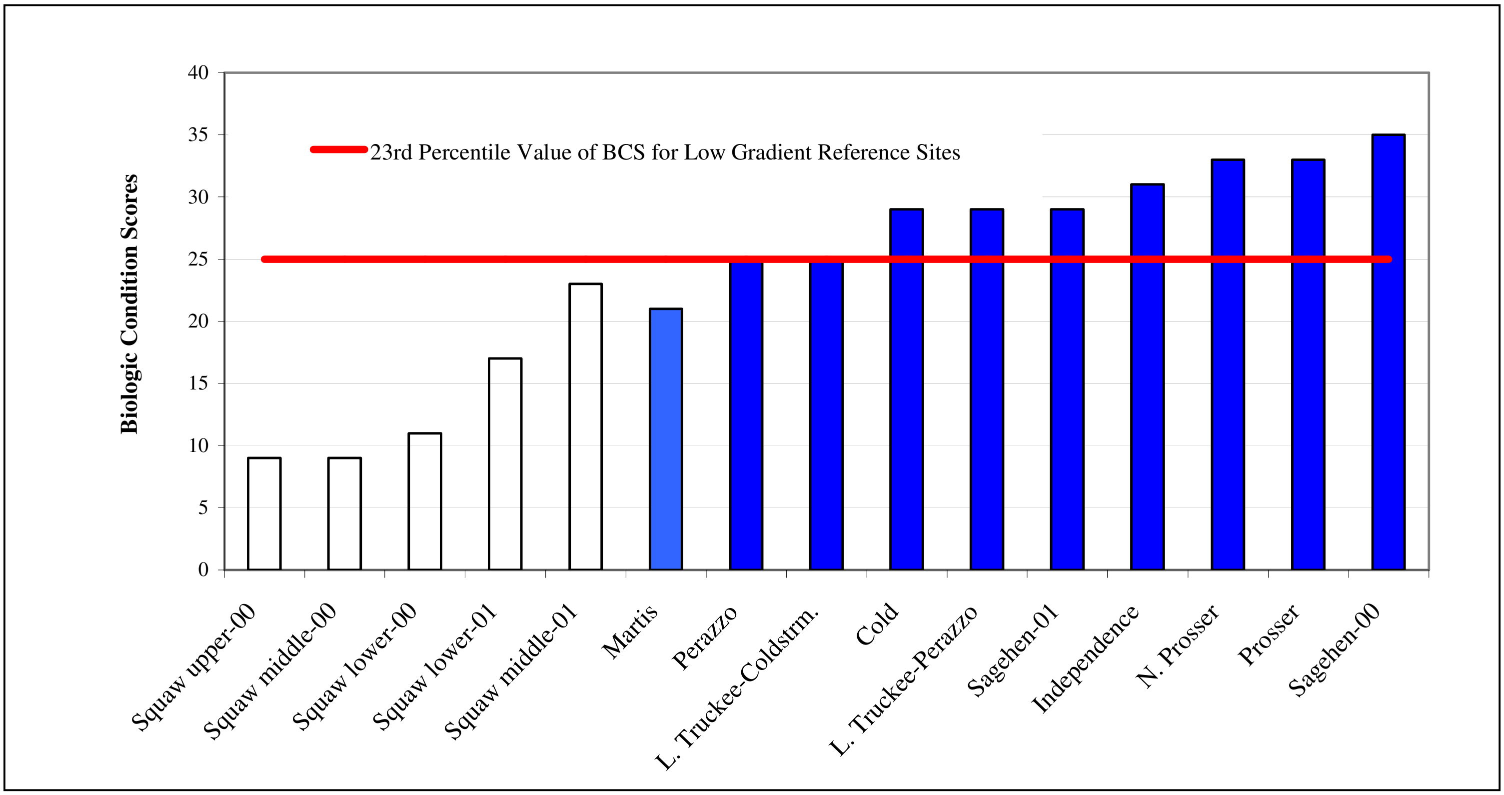
Comparison of numeric target and existing conditions
Table 3-4 shows the biologic condition scores for the meadow reach of Squaw Creek calculated from 2000 and 2001 bioassessment data. Figure 3-1 shows the Squaw Creek meadow reach biologic condition scores in comparison to low gradient reference sites.

Table 3-4
Squaw Creek Meadow Reach Biological Condition Scores, 2000-2001

Biotic Metric	Lower Meadow 2000	Middle Meadow 2000	Upper Meadow 2000	Lower Meadow 2001	Middle Meadow 2001
Biotic Index score	1	1	1	1	3
Taxa Diversity score	1	1	1	3	3
EPT Diversity Index score	1	1	1	3	3
%EPT Taxa score	3	1	1	1	3
Number of Sensitive Taxa score	1	1	1	3	3
%Tolerant Taxa score	1	1	1	5	5
R-50 Index score	3	3	3	1	3
Biological Condition Score	**11**	**9**	**9**	**17**	**23**
Average Squaw Creek Meadow Reach 2000 Biologic Condition Score = 10				**Average Squaw Creek Meadow Reach 2001 Biologic Condition Score = 20**	

The average biologic condition scores for the meadow reach sites improved by approximately 100 percent from 2000 (when flows in Squaw Creek were intermittent) to 2001 (when flows were continuous). These data suggest that flow conditions as well as sedimentation negatively affect in-stream biologic communities. Because of the variability in data between years, most likely due to flow conditions, comparing an average value for all data to the target score may not be meaningful. However, a reasonable baseline for comparison is the data collected in 2001, when flows in Squaw Creek were more comparable to reference site flows. These data show an average biologic condition score of 20, which represents an approximate 25 percent improvement needed to meet the numeric target of 25.

Figure 3-1
Comparison of Squaw Creek Meadow Reach Biologic Condition Scores (white bars) to Low Gradient Reference Streams (shaded bars), 2000 – 2001.



4. SOURCE ANALYSIS

The purpose of this source analysis is to identify and estimate the relative magnitudes of sediment sources to Squaw Creek, and to demonstrate that all major sediment sources have been considered in establishing load reductions to meet the numeric targets. This source analysis focuses on sources of sediment from land disturbance categories rather than individual land managers or dischargers. Loading estimates are expressed in U.S. short tons (2,000 lbs. per ton).

Several sediment-related studies were reviewed during development of this source analysis (Woyshner and Hecht, 1987; McGraw et al., 2001; Bullard et al., 2002). There is general consistency regarding the conclusions of these reports; that is, Squaw Creek's sediment load appears to be elevated in comparison to literature values and/or other regional streams. For example, Woyshner and Hecht concluded that Squaw Creek's "transported sediment is elevated in comparison to other regional watersheds. The available coarse sediment appeared large in relation to the transport capacity." McGraw et al. modeled sediment loading from major tributaries to the middle Truckee River. Of the ten tributaries studied, Squaw Creek's sediment loading to the Truckee River was the highest, contributing 35 percent of the middle Truckee's total sediment load.

Bullard et al. completed a sediment source study for Squaw Creek and concluded that the Squaw Creek watershed is characterized by excessive sediment discharge primarily related to land use activities. However, Bullard partly drew on previous work done by McGraw et al. to make comparisons between the north and south forks of Squaw Creek, including an incorrect and misinterpreted statement regarding the two forks' respective sediment load contributions that appeared to contradict the conclusions of the study. Bullard (p. 56) stated that "according to watershed modeling results by McGraw et al (2001), the south fork produces about 15 percent of the sediment load of Squaw Creek and the north fork produces 20 percent." At first glance, simple accounting would then suggest that the majority of Squaw Creek's sediment loading (65 percent) must come from the low gradient meadow reach or other areas with little land disturbance, which was not substantiated by the report's conclusions.

After further research into this apparent contradiction, it was evident that the statement was incorrect and misstated McGraw's results. A correct statement would read "according to the watershed modeling results by McGraw et al. (2001), of the middle Truckee River's total sediment load, the south fork produces about 15 percent and the north fork produces 20 percent." This subtle distinction is important, because McGraw et al. did not report sediment loading to each individual tributary; rather, how much sediment each tributary contributes to the Truckee River. Re-checking of McGraw's modeling results by subwatershed indicated that 35 percent of the sediment load to the middle Truckee River is attributed to Squaw Creek, and that 35 percent consists of 20 percent from the north fork and 15 percent from the south fork. Once the correction is made, the statement becomes consistent with the conclusions of Bullard et al. and others. For example, because the north fork watershed is approximately twice the area of the south fork, when normalized by area, McGraw's modeling results show that the south fork produces nearly twice the sediment per unit area than the north fork. This is consistent with

Woyshner and Hecht's study, which noted that the south fork generates approximately twice as much runoff per unit area as the north fork subwatershed.

Although the general conclusions were consistent, disparate study objectives and data collection methods made numerical comparisons between the studies difficult and confounded attempts to derive meaningful average values on which to base loading estimates. More significantly, the studies did not contain details on specific sediment sources needed for this analysis. In-stream sediment concentrations and concurrent stream flow data are very limited for Squaw Creek, although SVSC does monitor suspended sediment and other constituents in Squaw Creek at numerous locations associated with the ski area. However, quantitative flow data has not been consistently collected, so no sediment loading estimates can be made from this dataset.

Due to these challenges, this source analysis does not attempt to synthesize information from all the above data sources; rather, it relies on information from one study that was determined by Regional Board staff to be the most useful for TMDL development, because it is the most recent, watershed-specific study that contained sufficient detail to segregate sediment sources by land uses. This study was conducted in 2001 and 2002 in support of a Master of Science thesis in hydrology (Maholland, 2002), and is discussed in detail below.

This section presents a screening-level analysis of sediment delivery based on field measurements of gross erosion potential. As such, the accuracy of these sediment delivery estimates may be within an order of magnitude of actual loads. These estimates are most useful to understand the *relative* contribution of sediment from different erosional processes and land uses in the watershed, rather than absolute values of sediment delivery.

4.1 DATA AND METHODS

4.1.1 Overview

The sediment delivery estimates presented here are based primarily on erosion rate data and aerial photography analysis completed as part of a Master of Science thesis (Maholland, 2002). Erosion rates were measured at sixteen locations throughout the watershed in 2001 and 2002. These rates were used to generate erosion potential estimates, which were extrapolated to various landscape units throughout the watershed using a Geographic Information System (GIS) developed for the Squaw Creek watershed. The erosion potential estimates were scaled (reduced) to account for hillslope sediment storage by applying sediment delivery ratios determined from the average slope of Squaw Creek subwatersheds. Finally, sediment delivery to stream channels from various land uses was determined by analyzing a spatial land use data layer in conjunction with the erosion potential data layer to estimate sediment loading from various land uses in the Squaw Creek watershed.

Estimates of sediment contributions from channel bank erosion were based on long-term aerial photography analysis and global positioning system (GPS) field data. Contributions from large road cuts were determined by volumetric estimates of sediment losses calculated from GPS mapping. Sediment estimates from road sanding operations were based on road sand application records from Placer County for 2002 (Boswell, pers. comm., in Maholland, 2002), and adjusted for the miles of paved roads located in the Squaw Creek watershed.

Discussion of Terminology

Several terms introduced in this section require some discussion for clarity. "Erosion" and "sedimentation" (or sediment delivery) are two closely related processes whose terms are often used interchangeably. Erosion is defined as the detachment or breaking away of soil particles from a land surface by some erosive agent (wind, water, ice, gravity). Sedimentation is the subsequent transport of the detached particles to another location. In this source analysis, we attempt to clearly distinguish between estimates of erosion and estimates of sedimentation to recognize that not all eroded material is delivered to the stream. We use the term "sediment delivery estimate" to describe the amount of eroded material that is delivered to the stream channel. The term "sediment load," which is often used to describe sediment that is actively transported in a stream channel, is used here synonymously with "sediment delivery estimate."

"Controllable" sediment sources are defined as those that are associated primarily with human activity and will typically respond to mitigation, restoration, or improved land management. "Uncontrollable" sediment sources means those sources associated with naturally-occurring erosion and sediment delivery, mostly from undisturbed areas; although it is recognized that control of naturally-occurring erosion is certainly possible.

4.1.2 Erosion Rate Data Collection and Analysis

Erosion Pin Transects

Erosion rates were measured using erosion pin transects, a standard method used for measuring soil losses or gains on hillslopes. They consist of a small diameter pin inserted into the soil, using the top of the pin as the measurement datum (United Nations FAO, 1993). To determine the overall average movement occurring at a site for the sampling period, the change (+/-) in pin measurement height between visits was calculated. Positive values for change in pin height indicated deposition at the point, and conversely, negative values indicated erosion. The absolute values of the calculated change values were then summed to indicate the overall movement at the pin for the sampling period. The absolute value was used to 1) recognize that deposition at a pin is a result of erosion from some point above, so summing the absolute values of the change values provides an estimate of the overall movement on hillslopes, and 2) ensure that the rate of movement at a site is depicted accurately such that instances of erosion and deposition occurring at the same pin do not negate each other. An average movement rate by site was calculated by summing the overall movement obtained for each pin and dividing by the number of pins, yielding a movement rate for the sampling period (Wells and Gutierrez, 1982, in Maholland, 2002).

Erosion pin transect locations were selected from aerial photographs and field reconnaissance, taking into account factors such as climate, vegetation cover, land use, and geologic setting.

Representative areas of dominant land use and land cover types within the watershed were selected for measurement and included:

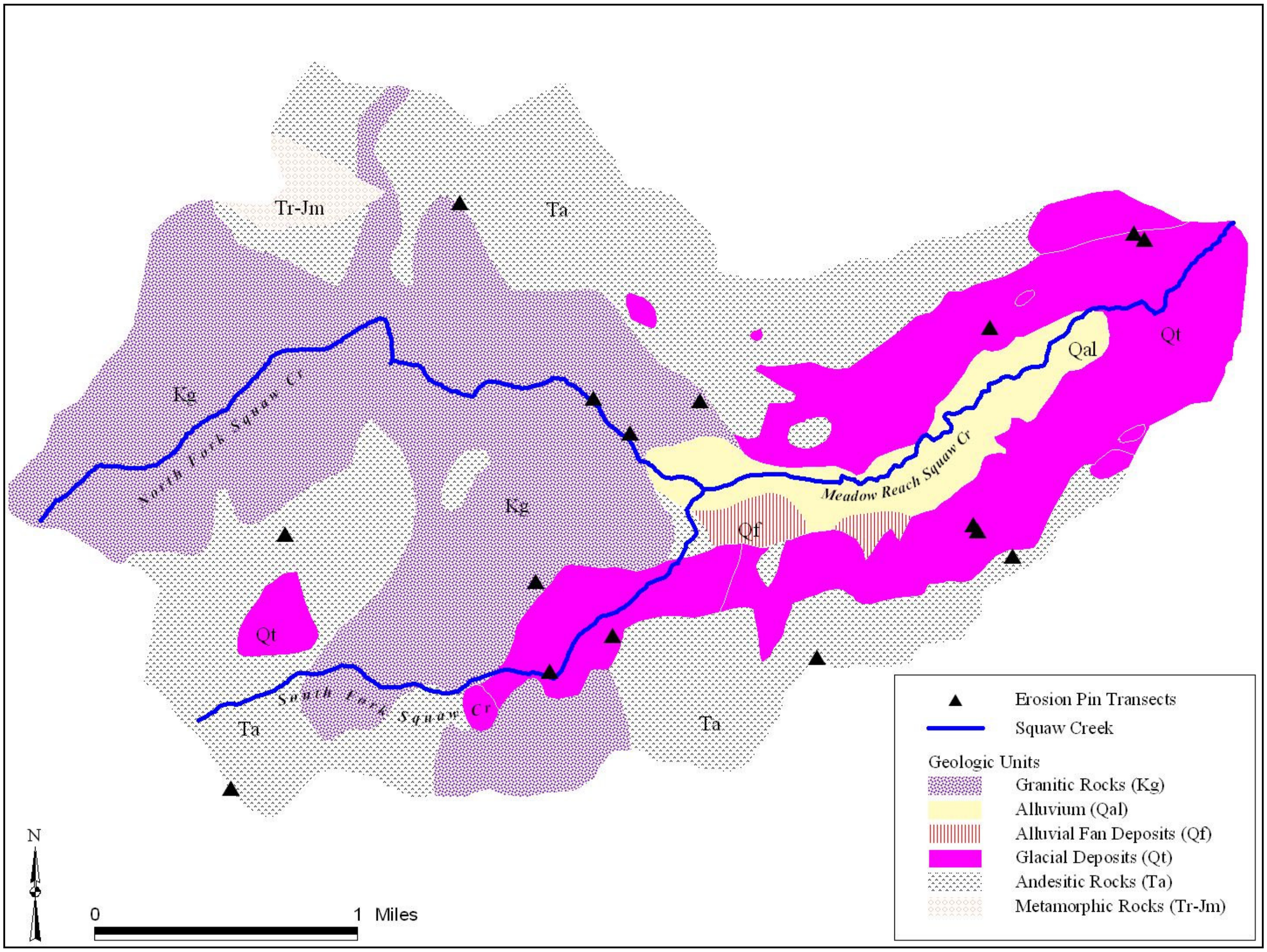
- Exposed rock/regolith (unconsolidated rock) slopes
- Undisturbed mixed conifer hillslopes
- Undisturbed slopes having chaparral cover
- Erosion associated with graded ski runs and dirt roads

Sixteen erosion pin transects were installed and sediment movement was measured from May through November 2001, and during the spring 2002 snowmelt runoff period. Table 4-1 describes the land use and geology represented at each erosion pin site. Figure 4-1 shows the locations of the erosion pin transects through the watershed and associated geologic units.

Table 4-1
Erosion Pin Site Descriptions

Erosion Pin Site	Description	Land Use Category	Geologic Unit
EPII-1	On compacted ski slope behind golf course	Ski Run	Glacial
EPII-10	West of top of Red Dog chair, downslope of road	Dirt Road near Ski Run	Volcanic
EPII-2	Undisturbed, mixed conifer	Undisturbed/Vegetated	Glacial
EPII-4	Under red fir forest canopy near top of ridge	Undisturbed/Vegetated	Volcanic
EPIII-1	Undisturbed, mixed conifer	Undisturbed/Vegetated	Glacial
EPIII-2	Mature shrubs & grasses; moderate slope	Undisturbed/Vegetated	Glacial
EPIII-3	Natural gully drainage, south facing, chaparral vegetation	Gully wall in undisturbed vegetated	Glacial & Volcanic
EPIII-4	Roadside cutslope in residential area	Paved Road Cutslope	Glacial
EPIV-2	Dirt road cutslope below vegetated ski run	Dirt Road Cutslope below Ski Run	Volcanic
EPIV-3	Moderately sloped ski run, sparse vegetation, dirt road above and below	Ski Run below Dirt Road	Granitic
EPIV-5	Near road, old excavation site	Dirt Road	Granitic
EPIV-9	Andestic hillslopes below Squaw Peak	Undisturbed/Exposed Rock Slopes	Volcanic
EPV-1	Coarse, sandy regolith; little vegetation	Undisturbed/Exposed Rock Slopes	Granitic
EPV-2	Coarse, sandy regolith; little vegetation	Undisturbed/Exposed Rock Slopes	Granitic
EPV-3	Steep andestic hillslope, sandy soils, sparse veg.	Undisturbed/Exposed Rock Slopes	Volcanic
EPV-7	Ski run, sparse vegetation	Ski run	Volcanic

Figure 4-1
Erosion Pin Locations and Associated Geologic Units



Calculation of Erosion Rates from Pin Data

For this study, it was assumed that precipitation was the primary (most effective) agent of sediment movement; therefore, movement at a site was a function of the total precipitation occurring during the sampling period (Maholland, 2002). Erosional processes such as dry ravel and slide, and soil creep (due to gravity, frost heaving, etc) are typically active even during relatively dry periods; therefore, these processes are also reflected in the measured sediment movement rates. Average annual rates of sediment movement were obtained by relating the precipitation that occurred during the sampling period to the average annual long-term precipitation. Annual average precipitation was calculated from precipitation data from 1993 to 2002, collected daily by the Squaw Valley Fire Department. Snow water equivalent values were computed by assuming an 8:1 ratio of snow depth to rain depth (NOAA, 2002, in Maholland, 2002).

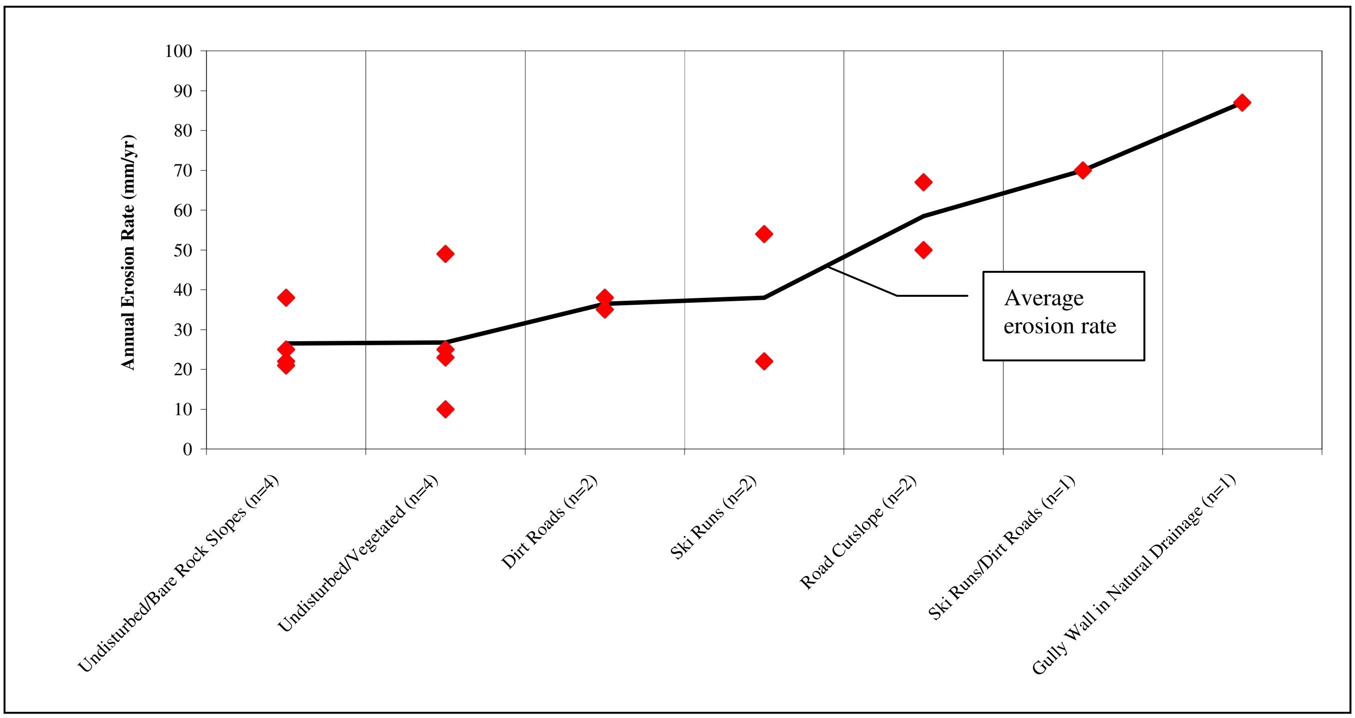
Equation 4-1 shows the computation used to derive annual erosion rates:

Equation 4-1: $M_A = (M_{SP} / PPT_{SP}) \times PPT_A$

M_A = Annual erosion rate (meter/year)
M_{SP} = Sampling period movement rate (meter/sampling period)
PPT_{SP} = Total precipitation for the sampling period (inches)
PPT_A = Average annual precipitation (inches)

Figure 4-2 shows the range of erosion rates (in mm/year) associated with land use types represented at the erosion pin transects. The observed relationship between increasing erosion rates and land disturbance is consistent with published literature on the topic (e.g., USEPA, 2005; Wemple et al., 1996; Weaver and Hagans, 2004; Ritter et al., 1995).

Figure 4-2
Range of Erosion Pin Rates and Associated Land Uses.



Average annual erosion rates were converted to annual estimates of erosion potential in tons per acre per year. Equation 4-2 illustrates this computation:

Equation 4-2: Erosion Potential (tons/acre/year) = M_a (m/yr) x 1,400 kg/m^3 x 0.00098 tons/kg x 4,047 m^2/acre

M_A = Annual erosion rate (meter/year)
Assumed bulk sediment density = 1,400 kilograms per cubic meter (Brady, 1974, Maholland, 2002 [unpublished spreadsheet data])
Conversion from kilograms to English long tons = 0.00098
Conversion from square meters to acres = 4,047

The resulting values, along with data on slope, geology, soils, vegetation and land use were combined to develop a GIS layer of hillslope erosion potential, discussed further below.

GIS Data and Analysis

The GIS database for the Squaw Creek watershed was developed by the University of Nevada's Desert Research Institute (DRI) and Maholland. The database includes public domain data sets and new digital data created specifically for this study. Arcview® version 3.2a GIS software was used to create and analyze data layers. Data layers include 10-meter resolution Digital Elevation Models (DEMs), 1998 Digital Orthophotoquads (DOQs), scanned topographic maps, and hydrology, soils, geology, and road layers. These were modified and enhanced based on field reconnaissance, historic aerial photographic analysis, and field data analysis. Additional digital information was created as well, based on field mapping and observations, and includes vegetation, fluvial geomorphology of the meadow portion of the creek, and current land use and land cover.

The land use data layer for the Squaw Creek watershed was created using 1998 digital DOQs, 1997 aerial photography (scale 1:16,000), and field observations. Sixteen categories were developed for the watershed, based on texture, tone, color, shape, field reconnaissance, and watershed knowledge. These categories were digitized into the GIS to assist in the spatial evaluation of potential sediment sources.

A polygonal GIS data layer of hillslope erosion potential was developed to synthesize information on slope, vegetation, geology, soils, erosion rates and land use types. The erosion potential estimates were multiplied by a sediment delivery ratio (SDR), a scaling factor that accounts for the potential for hillslope sediment deposition and storage. SDRs were calculated according to the Equation 4-3:

Equation 4-3: $SDR = 0.627 (Slope)^{0.403}$ (Reid and Dunne, 1996).

(Slope) = the percent slope of the main stem channel for each subwatershed.

Key data fields used to assign erosion and sediment delivery potential to each polygon in the data layer are shown in Table 4-2.

Table 4-2
Hillslope Erosion Potential GIS Data Layer Field Descriptions

Field Name	Description
1) acres	Acreage of each polygon, calculated using Arcview.
2) sed_tons_acre	Erosion potential in tons per acre. Estimated using annual erosion rates, extrapolated across the watershed for similar areas.
3) sed_tons_yr	Erosion potential in tons per year. Calculated by multiplying fields 1 and 2, above.
4) slopemain	Percent slope of mainstem stream channel in each subwatershed. Calculated using Arcview hydrologic modeling tools, then used to calculate SDR (see below).
5) delivratio	Sediment Delivery Ratio (SDR) for each polygon in a given subwatershed. Calculated based on slope of subwatershed (see Equation 4-3).
6) sedtonsyr	Sediment delivery potential in tons per year. Calculated by multiplying fields 3 and 5.

Eroded material from hillslopes within 10 meters of drainages was assumed to have the highest potential to reach the stream channel (personal communication, B. Maholland, 2003). Therefore, the data layer of erosion potential was "clipped" to a 10-meter "buffer" surrounding all drainages, which are defined as streams and dirt roads. Dirt roads were included to account for their ability to function as sediment conveyances.

Finally, sediment delivery estimates were attributed to source categories by analyzing the land use, streams and road data layers with the erosion potential layer to determine which land uses were adjacent (i.e., within the 10-meter buffer) to drainages. The output was then converted by Regional Board staff to U.S. tons (2,000 lbs per ton) using a conversion factor of 1.12 U.S. tons per English long ton. U.S. tons are the units used to express the loading information in this document.

Sediment loads were attributed to ski runs by determining the number of acres and associated sediment delivery of ski runs within 10 meters of all drainages. Next, sediment contributions attributed to dirt roads were estimated by calculating the acreages and associated sediment delivery within the 10-meter buffer around dirt roads centerlines (to include the dirt road itself) in otherwise undisturbed areas that do not contain ski runs or urban land uses.

Sediment contributions from commercial and residential areas were estimated by determining the amount of acres of these land use types within 10 meters of any stream drainage. Because no erosion rate measurements were made for specifically for these areas, Regional Board staff assigned the lowest measured erosion rates and sediment delivery ratios to residential and commercial land use acreages. This assumption accounts for the decreased surface area available for erosion due to paved surfaces, and that residential and commercial areas are typically stabilized with landscaping and generally located in areas of flatter topography. These assumptions are reasonable because even if actual erosion rates and delivery ratios were closer to the mid-range of observations for the watershed, the change in the relative contribution to the total sediment budget would less than 3 percent.

Road cuts that had large, observable volumetric losses were mapped by Maholland, digitized and assigned estimated volumes to determine their contribution to the sediment load. Road sand contributions were determined from the total amount of road sand reported applied for 2002 for Placer County, adjusted to the paved road mileage in the Squaw Creek watershed. This estimate is reasonable because even if actual road sand application rates were doubled, the change in the relative contribution to the total sediment budget would be less than one percent.

Sediment contributions attributed to naturally occurring erosion were determined from the acreages of undisturbed land within 10 meters of stream drainages only (i.e., dirt roads were not counted as drainages for this source category). Undisturbed land was defined as areas that did not have a road, ski run, or urban land use in the 10-meter buffer.

4.1.3. Aerial Photography Analysis

Maholland analyzed aerial photographs from 1939, 1987 and 1997, and conducted GPS stream mapping in 2001 to assess long-term stream channel migration in the meadow reach of Squaw Creek to estimate sediment from in-channel bank erosion. Average stream migration was calculated from the average migration distances between the 1939 and 2001 mapped thalwegs (stream centerlines) for sections of the creek. The sediment volume was estimated by calculating the area of material eroded, the average channel depth, and applying an average soil density of 1.5 grams per cubic centimeter. This value was then divided by the number of years for which photo and mapping data were available (1939-2001), to yield an average yearly volume of sediment contributed by channel bank erosion.

4.2 SUMMARY OF SEDIMENT SOURCES

The results of the sediment source analysis are presented in Table 4-3. The estimates for all sediment source categories except alluvial channel erosion and road cuts represent conditions observed in the watershed in 2001 and 2002. Alluvial channel bank annual estimates are based on long-term stream channel migration estimates and distributed uniformly based on the period from which photos and GPS mapping were available (1939-2001). Annual contributions from major road cuts were estimated by assuming that many roads associated with the road cuts were constructed approximately 40 years ago and that sediment loss from the road cuts occurred uniformly since that time (Maholland, 2002).

Table 4-3
Sediment Delivery Estimates, Squaw Creek Watershed
(Rounded to nearest 100 tons)

Sediment Source Category	Total Sediment Delivery by Source Category (tons/year)	Percent of Total by Source Category
Dirt Roads	**9,300**	25%
Major Dirt Road Cuts	**900**	2%
Road Traction Sand	**300**	1%
Residential/Commercial Areas	**200**	1%
Graded Ski Runs	**9,000**	24%
Alluvial Channel Erosion	**4,300**	11%
Undisturbed Areas	**14,000**	37%
*Uncontrollable Sources**	**16,100**	42%
Controllable Sources	**21,800**	58%
Total Annual Sediment Delivery	**37,900**	100%

*This is considered the best estimate of current naturally occurring sediment delivery. The estimate shown includes 50 percent (rounded to 2,100 tons/year) of the annual channel bank contribution and 100 percent (14,000 tons/year) of sediment delivery from undisturbed areas.

Figure 4-3 shows the percent of total sediment load by source category. The source analysis suggests that approximately 60 percent of the sediment delivery may be attributed to human activities and approximately 40 percent is attributed to naturally occurring erosion. Given the current information, it was not possible to determine how much alluvial channel erosion is due to human activities and how much is due to natural erosion; therefore, the sediment loading ratio of natural to anthropogenic hillslope sources was used to allocate 50 percent of channel bank erosion to natural sources and the remainder to controllable sources. The distribution of the primary sediment-contributing land uses identified in the source analysis as "controllable" is shown in Figure 4-4.

Figure 4-3
Summary of Sediment Sources

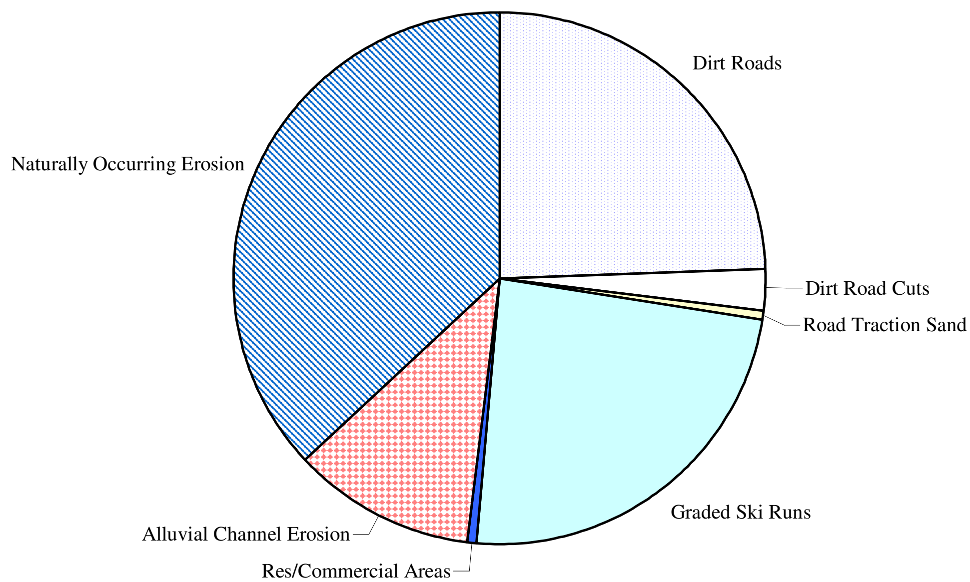
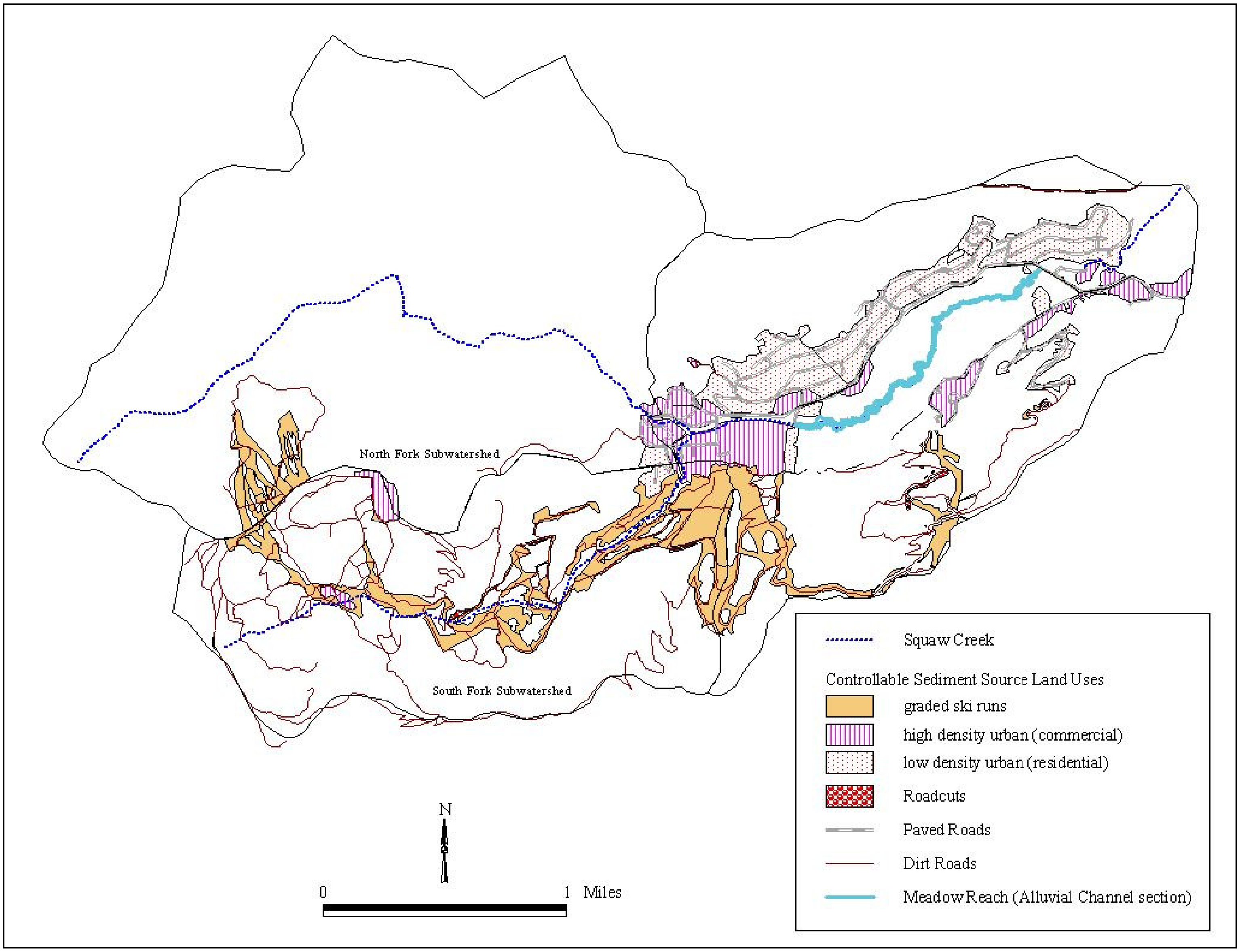


Figure 4-4.
Distribution of Controllable Sediment Source Land Uses in the Squaw Creek Watershed



5. LOADING CAPACITY AND LINKAGE ANALYSIS

Loading capacity is defined as the maximum amount of a pollutant that a water body can receive without violating water quality standards [40 CFR 130.2 (f)]. The loading capacity plus a margin of safety (MOS) is the TMDL and can be expressed in any appropriate terms (i.e. pounds per day, tons per year, etc.). The linkage analysis describes the link between the loading capacity and the applicable water quality standards (as interpreted through numeric targets) and provides the rationale for load reductions and allocations. The loading capacity and linkage analysis are presented below.

5.1 SQUAW CREEK LOADING CAPACITY

The loading capacity must meet water quality standards and support the beneficial uses of Squaw Creek. The TMDL interprets these standards based on coldwater aquatic life protection (the most sensitive beneficial use) through in-stream indicators and numeric targets, with the following baseline assumptions:

- There is some amount of in-stream sediment loading above natural background conditions under which beneficial uses will be supported and narrative water quality objectives met. This assumption is reasonable because of the inherent natural annual and seasonal variability of in-stream sediment levels and the variability of estimated sediment loads in reference watersheds.

- Some degree of water quality degradation and beneficial use impairment occurred due to land development and other activities in the watershed before the adoption of the statewide Nondegradation Policy in 1968 and Regional Board adoption of water quality standards for the creek in 1967.

These assumptions demonstrate that it is not necessary for the Squaw Creek watershed to reflect completely natural or pre-disturbance conditions in order to achieve water quality standards. Since baseline conditions for interpretations of standards reflect historic degradation, restoration of the creek to "pristine" conditions is not required as long as beneficial uses are adequately supported.

Sediment load reductions needed to protect beneficial uses are estimated based on mathematical comparisons of existing and target conditions as described by EPA (1999), then applied to the annual sediment loading of 37,900 tons/year to estimate the load capacity. The biologic condition score was selected for estimating reductions because it represents the key benchmark of success to interpret beneficial use support. It is also a sensitive, integrative indicator of aquatic habitat suitability, including the effects of sediment discharges from multiple sources over time. Although sediment substrate composition is an important indicator of beneficial use support, its variability is affected not only by sediment supply, but also by the timing, magnitude and duration of peak flows which affect sediment transport capacity, influencing substrate particle size. Due to this variability, the stream channel substrate numeric targets (percent fines and sand and D-50 particle size) were not used as a basis for estimating load reductions.

The overall load reduction needed to protect aquatic life beneficial uses is estimated at 25 percent. This estimate is based on comparison of the biologic condition scores of the meadow reach of Squaw Creek, using 2001 data as the baseline, with the biologic conditions found in low gradient reference streams in the Truckee River watershed, as shown in Equation 5-1:

Equation 5-1:

Sediment load reduction to achieve desired conditions = [(Target BCS) – (Existing BCS)] / Existing BCS.

Therefore, (25 – 20) / 20 = <u>25 percent reduction</u> in sediment loading to achieve desired in-stream conditions.

The loading capacity is estimated as shown in Equation 5-2:

Equation 5-2:

> Loading capacity = (existing sediment load) – (load reductions needed to achieve desired biologic condition).

Applying this equation to the current sediment load and needed reductions, the loading capacity of Squaw Creek is shown in Equation 5-3:

Equation 5-3:

Loading Capacity = 28,425 tons/year = (37,900 tons/year) – (37,900 *0.25)

The quantitative relationship between the estimated sediment loading reduction and the corresponding percentage of improvement in biologic condition scores is not known. Absent these data, Regional Board staff assumes that a simple 1:1 relationship between sediment load reductions and biologic health improvement provides a reasonable basis for establishing needed reductions. Although the estimated reduction applies to the total sediment load, it is important to note that control of fine sediment sources (particle sizes <1mm) will be needed to meet the numeric targets for substrate composition and corresponding improvement in biologic condition scores.

Sediment loading reduction and loading capacity are estimated here only to give a relative sense of the watershed-wide improvements needed to protect water quality and beneficial uses. The success of the Squaw Creek TMDL will not be directly measured by sediment mass loading reductions, because that is not a practical indication of beneficial use protection due to the inherent natural variability of sediment delivery and the uncertainties associated with accurately measuring sediment reduction. The practical benchmarks to determine if desired conditions (and thus, the loading capacity) are achieved are the numeric targets that measure the in-stream response to iterative watershed-wide BMP implementation and maintenance.

5.2 LINKAGE ANALYSIS

The linkage analysis describes the relationship or link between the numeric targets and the estimated loading such that the determination of sediment loading capacity is appropriate to support the beneficial uses for the waterbody. Linkage between sediment delivery to the creek and impairment of aquatic life beneficial uses was established using best professional judgment, modeled loading estimates (Herbst, 2002) and sediment related in-stream physical habitat parameters.

Best professional judgment was based on scientific literature supporting the link between hillslope development and associated land disturbance to increased erosion and sediment delivery to streams channels (USEPA, 2005; Wemple et al., 1996; Weaver and Hagans, 2004; Ritter et al., 1995). The link to impairment of beneficial uses due to excessive sedimentation was further established based on correlations between modeled sediment loading predictions, channel substrate conditions and biologic health from Herbst (2002). The link between the level of impairment and sediment loading to the creek was calculated based on the difference between biologic condition scores found in the meadow reach when flowing water (riffle habitat) was present and those of the reference stream sites.

6. TMDL AND LOAD ALLOCATIONS

TMDLs are the sum of wasteload allocations for point sources, load allocations for nonpoint sources, and a margin of safety. There are currently no NPDES-regulated point sources in the watershed; therefore, the wasteload allocation is zero. However, NPDES permits to control stormwater discharges may be issued in the future (e.g., to public facilities that incorporate source areas such as paved roads and parking lots). In that event, the currently assigned load allocation(s) to those source categories would be expressed as wasteload allocation(s) in the permit. Allocations are discussed below and summarized in Table 6-1. Table 6-2 shows the existing controllable hillslope sediment source categories by major jurisdiction in the watershed, with associated load allocations based on those percentages. In-stream channel erosion is not specifically allocated to any one entity, but is it anticipated that voluntary and cooperative riparian enhancement projects along with improvements in upslope conditions will result in allocation attainment over time.

Table 6-1
TMDL, Allocations and Percent Reductions Needed by Sediment Source Category

Sediment Source Category	Sediment Delivery by Source Category (Tons/year)	Percent Reduction Required	Load Allocation* (Tons/year)
Dirt Roads	9,300	60%	3,700
Dirt Road Cuts	900	50%	450
Road Traction Sand	300	25%	200
Residential/Commercial Areas	200	25%	150
Graded Ski Runs	9,000	50%	4,500
Alluvial Channel Erosion (50 percent of the total load from channel bank erosion is assumed to be controllable)	2,100	10%	1,900
Total Controllable Sources	***21,800***	***50%***	***10,900***
Alluvial Channel Erosion (50 percent of the total load from channel bank erosion is assumed to be naturally occurring)	2,100	0%	2,100
Undisturbed Areas	14,000	0%	14,000
Total Uncontrollable Sources	***16,100***	***0%***	***16,100***
Total Existing Sediment Load	37,900	Load Allocation to Existing Sources	27,000
Overall Reduction Needed to Achieve TMDL	25%	Load Allocation to Future Growth	150
TMDL = LA (existing and future sources) + MOS	**28,425**	Load Allocation to Margin of Safety (4%)	1,275
		Total Load Allocations	**28,425**

*Allocations to existing sources rounded to nearest 50 tons.

Table 6-2
Existing Controllable Hillslope Sediment Source Categories and Load Allocations by Jurisdiction/Major Land Owner

Sediment Source Category	Percent of Source Category in Jurisdiction	Sediment Delivery (Tons/year)	Percent Reduction Needed	Load Allocation (Tons/year)
Dirt Roads		**9,300**	**60%**	**3,700**
SVSC	83%	7,719		3,088
Resort at Squaw Creek	13%	1,209		484
Placer County	4%	372		149
Major Dirt Road Cuts		**900**	**50%**	**450**
SVSC	71%	639		320
Resort at Squaw Creek	29%	261		130
Placer County	unknown	unknown		unknown
Road Traction Sand		**300**	**25%**	**200**
Placer County	100%	300		200
Residential/Commercial Areas		**200**	**25%**	**150**
SVSC	18%	36		27
Resort at Squaw Creek	4%	8		6
Placer County	76%	152		114
Intrawest Village at Squaw Creek	2%	4		3
Graded Ski Runs		**9,000**	**50%**	**4,500**
SVSC	93%	8,370		4,185
Resort at Squaw Creek	7%	630		315

* Individual allocations may sum to greater than the total allocation due to rounding.

The TMDL (i.e., loading capacity plus a MOS) for Squaw Creek is 28,425 tons per year. To achieve the TMDL, allocations are assigned to the existing controllable sediment source categories, future growth (development), naturally occurring erosion and an explicit margin of safety, as shown in Equation 6-1:

Equation 6-1:

TMDL = WLA + LA (existing controllable sources) + LA (future sources) + LA (naturally occurring sources) + explicit MOS (4% of existing load)

Therefore, the TMDL and allocations for the Squaw Creek Sediment TMDL are:

Equation 6-2:

28,425 tons/year = 0 + 10,900 + 150 +16,100 + 1,275

The load allocations shown in Table 6-1 reflect assumptions about the efficiency of erosion control actions such as implementation of Best Management Practices (BMPs). Factors such as location, design and maintenance practices can have substantial influence on erosion control effectiveness, particularly for fine sediment. For example, a source control BMP that fully stabilizes a disturbed area may approach 100 percent effectiveness, whereas a poorly maintained treatment BMP may have zero effectiveness.

Reuter et al. (2001) reports median results for BMP effectiveness in reducing total suspended solids (TSS) concentrations ranging from 46 to 97 percent. This estimate is based on investigations of BMP effectiveness in the Lake Tahoe basin, a nearby watershed with similar land uses, topography and climate to the Squaw Creek watershed. Comparison to values reported in national erosion and sediment control literature for BMP effectiveness shows consistency between estimates, shown in Table 6-2.

Table 6-3
Literature Values Reported for Various Erosion and Sediment Control BMP Efficiencies

BMP Type	Sediment Source Category	Efficiency	Parameter	Reference
Maintain roadside vegetation	Dirt roads, road cuts, residential/commercial areas	90% removal (average)	Sediment	USEPA, 1993 (in *Stormwater Manager's Resource Center*, Pollution Prevention Fact Sheet)
Sediment traps/basins	All	60-90%	Sediment	*Stormwater Manager's Resource Center*, Erosion and Sediment Control Fact Sheet
Mulches	Ski runs, construction Areas	65-97%	TSS, Sediment	*Stormwater Manager's Resource Center*, Erosion and Sediment Control Fact Sheet
Vegetative Stabilization	Ski runs, dirt roads, road cuts, construction areas	Up to 99%	Sediment	*Stormwater Manager's Resource Center*, Erosion and Sediment Control Fact Sheet

Based on these results and considering both source control and treatment BMP use, staff conservatively estimated an average BMP effectiveness of 50 percent for reducing sediment yields from disturbed hillslope areas such as ski runs and road cuts.

Dirt road BMPs are expected to have greater than 50 percent effectiveness due to the potential to limit road use and control runoff; therefore, efficiency was estimated at 60 percent. Experience with Caltrans and counties in the area indicates that sediment associated with road sanding operations can be reasonably reduced at least 25 percent through collection activities and other BMPs. This 25 percent efficiency is assumed be achievable for all paved area sediment source categories, including residential and commercial areas.

Erosion from alluvial channel banks is expected to decrease in response to improved upslope conditions over time; however, data are not available to derive an expected reduction. Therefore, the loading reduction from in-stream channel erosion is conservatively estimated at 10 percent, based the estimated percentage this source contributes to the overall sediment loading to Squaw Creek.

The load allocation to future development in the watershed was set equal to the load allocated to existing residential and commercial areas. Because permits associated with construction activities require control of sediment discharges during the initial construction phase, and post-construction stabilization is expected to occur similarly to existing residential and commercial areas, this is a reasonable basis for allocation. Additionally, there is a load allocation to an explicit margin of safety to account for uncertainties in this analysis. No reduction in estimated "naturally occurring" sediment delivery from undisturbed lands is assigned.

7. MARGIN OF SAFETY, SEASONAL VARIATION AND CRITICAL CONDITIONS

Section 303(d) of the Clean Water Act and the regulations at 40 CFR 130.7 require that TMDLs be established at levels necessary to attain and maintain the applicable narrative and numeric water quality standards, and must include a margin of safety (MOS) that accounts for any lack of knowledge or uncertainty in the TMDL analysis. The TMDL must also take into account seasonal variations and critical conditions to assure that the load allocations will support water quality standards at all times.

An explicit or implicit MOS may be used. An explicit MOS can be provided by reserving (not allocating) part of the total loading capacity and requiring greater load reductions from existing and/or future source categories. An implicit MOS can be provided by conservative assumptions in the TMDL analysis. The Squaw Creek TMDL includes both an implicit and explicit margin of safety. The conservative assumptions that comprise the implicit MOS are outlined in the following section. The explicit margin of safety reserves 1,275 tons (or approximately 4 percent of the total loading capacity) for uncertainties in TMDL analysis and BMP effectiveness.

7.1 UNCERTAINTIES AND CONSERVATIVE ASSUMPTIONS

It is difficult to accurately measure sediment loading and transport and the resulting effects as they occur throughout a watershed. There are substantial and poorly defined spatial and temporal lags between erosion, sediment delivery and the occurrence of sediment-related impacts on beneficial uses. For the most part, this TMDL analysis relied on data from field studies and GIS data that were developed specifically for Squaw Creek and the Truckee River watershed. Utilizing these types of data, rather than relying only on literature values or data from far-removed studies, provides an advantage in understanding and interpreting sedimentation processes in the watershed. Nonetheless, data interpretation, data limitations and the inherent variability of sediment-related processes can introduce varying degrees of uncertainty into the TMDL analysis

To ensure that water quality and beneficial uses will be adequately protected regardless of these uncertainties, conservative assumptions and interpretations were often made. These assumptions comprise the implicit MOS for the Squaw Creek TMDL and are summarized in Table 7-1.

Table 7-1
Summary of Uncertainties and Conservative Assumptions/Adjustments

Uncertainty in TMDL Analysis	Implications of Uncertainty	Adjustment to Account for Uncertainty
Inherent seasonal and annual variability in sediment delivery and in-stream impacts of sediment common to all stream systems.	Sediment delivery estimates may be greater or less than predicted.	The expression of the in-stream indicators as multi-year rolling averages or trends accounts for the inherent variability in annual sediment delivery rates. An explicit MOS reserves 4% of the loading capacity to offset uncertainties in sediment delivery and in-stream impacts.

Uncertainty in TMDL Analysis	Implications of Uncertainty	Adjustment to Account for Uncertainty
Accuracy of in-stream channel erosion estimates. Changes in channel bank locations were not mapped, so actual bank retreat rates were not available. It is undetermined if the stream has consistently widened and/or incised its channel over time (Kondolf, 2004).	In-stream erosion rates maybe over-predicted	None. In-stream erosion comprises a relatively small percentage of the total sediment load (even if over-estimated). The best available data were used for the estimate and are considered reasonable and conservative for this analysis.
Future effects of legacy sediment storage and streambed cleansing on beneficial uses.	In-stream responses to watershed conditions and improvements will vary.	The expression of in-stream indicators as multi-year rolling averages accounts for the inherent variability in annual sediment delivery rates, including the effects of stored sediment movement through the stream channel as hillslope inputs are decreased. Further, because the amount of stored sediment appears to be impacting beneficial uses, no "credit" was given to in-stream sediment storage potential in the source analysis.
Mathematical relationship between improvement in biologic health and estimated sediment load reductions.	Needed load reductions may be greater or less than predicted.	A linear (1:1) relationship was assumed between improvement needed in biologic condition scores and sediment loading reductions. A monitoring and review program and schedule will provide an ongoing mechanism to revise this assumption if, in the future, the Regional Board finds needed load reductions were under- or overestimated. Further, an explicit margin of safety is used to offset this uncertainty.
Effectiveness of BMP control strategies in attaining load reductions.	Effectiveness of BMPs may be greater or less than predicted.	Conservative estimates (25-60 percent) of BMP efficiencies were used to allocate loads to various sources. A monitoring and review program and schedule will provide an ongoing mechanism to adjust the TMDL if, in the future, the Regional Board finds that BMP effectiveness was overestimated. Further, an explicit margin of safety is used to offset this uncertainty.
Effect of BMPs implemented after TMDL studies were conducted is unknown.	Sediment loading may be over-estimated. Required load reductions may be partially met by BMPs implemented before adoption of the TMDL.	It is recognized in the TMDL that extensive BMP implementation is ongoing in the watershed. Extent and effectiveness of existing BMPs will be considered when evaluating progress toward meeting TMDL targets.
Degree of hydrologic connection of all dirt roads to stream channels, regardless of the road's proximity to a stream.	All dirt roads were assumed to have hydrologic connection to streams, therefore, sediment delivery attributed to dirt roads may be over-predicted.	None. This is a reasonable, conservative assumption, given the high concentration of dirt roads in areas of steep topography in the watershed.

Uncertainty in TMDL Analysis	Implications of Uncertainty	Adjustment to Account for Uncertainty
Long-term representativeness of hillslope erosion rates.	Most likely under-predicts sediment loads because erosion rates were collected during period of low or no precipitation (Kondolf, 2004).	Long-term rainfall records (1993-2002) were factored into erosion rate calculations to account for average annual expected precipitation. Additional erosion rate data were collected following peak snowmelt runoff period (spring/early summer 2002). In-stream indicators are expressed as multi-year rolling averages or trends to account for the inherent variability in annual sediment delivery rates.
Applicability of localized erosion rates to areas across the watershed.	Extrapolation of localized rates most likely over-predicts watershed-wide erosion potential (Ritter, et al., 1995).	None. May be offset by potential for under-prediction of erosion rates due to limited rainfall during study period.
Data on sediment collected from culverts draining residential areas were not available; therefore, staff relied on alternate analysis.	Resulting estimate may over-predict sediment delivery attributed to paved areas.	Load reductions needed from paved areas were based on reasonably achievable (low range) estimates of BMP efficiencies.

7.2 SEASONAL VARIATIONS AND CRITICAL CONDITIONS

All stream ecosystems, whether or not they have been disturbed by human activities, exhibit seasonal and annual variations in the rate of sediment delivery to the stream and in the impacts of sediment on stream organisms during different stages of their life cycles. Furthermore, there may be significant temporal lags and spatial disconnects between hillslope erosion events and the impacts of sediment on in-stream uses. Sediment impacts may be more important if they affect critical conditions of an organism's life cycle than if they occur at other times; e.g., sedimentation of spawning gravels can have particularly significant effects on early developmental stages of fish. Also, geomorphic characteristics may predispose a stream section to be more sensitive to excessive sedimentation than others.

The TMDL accounts for critical conditions by establishing targets and allocations based on net long-term effects to the meadow reach of Squaw Creek, which appears to be most sensitive to sedimentation, due to its geomorphic characteristics. Use of benthic macroinvertebrates as indicators of in-stream habitat health further protects the most sensitive receptor of excessive sedimentation.

The Squaw Creek TMDL uses multiple targets and indicators in order to integrate the net cumulative effects of sedimentation over longer time frames. Together, these targets address the effects of sediment loading, transport, deposition, and impacts on beneficial uses. The TMDL attainment will be assessed using multi-year data based on rolling averages and trend analysis to account for natural seasonal and annual variations in sedimentation, with the recognition that trends may not be apparent within shorter time frames. The TMDL and load allocations are set at levels, which, over time will allow in-stream aquatic habitats to recover to a level that adequately supports aquatic life uses.

8. PUBLIC PARTICIPATION

Federal TMDL regulations require that the public be given the opportunity to review and comment on TMDLs. For TMDLs adopted as Basin Plan amendments in California, opportunities for public participation are provided through the procedures summarized in the USEPA Region IX *Guidance for Developing TMDLs in California* (2000), and through the California Environmental Quality Act (CEQA) review process.

The Lahontan Regional Board maintains mailing lists for parties interested in receiving draft Basin Plan amendments and/or hearing notices, and a separate mailing list for its agenda announcements. The Basin Plan amendment and CEQA review processes include opportunities for written public comments and for testimony at a noticed public hearing. Written responses are required for written public comments received during the noticed public review period, and staff respond orally to late written comments and hearing testimony before Board action is taken.

The Lahontan Regional Board's Basin Plan amendments (including draft TMDLs) are now made available on the Internet and publicized through press releases. Further opportunities for public participation are also provided in connection with review and approval of Regional Board-adopted Basin Plan amendments by the State Board and the USEPA. Documentation of public participation, including copies of hearing notices, press releases, written public comments and written responses, and tapes or minutes of hearing testimony will be included in the administrative record of the Basin Plan amendments for USEPA review.

8.1 SQUAW CREEK SEDIMENT TMDL PUBLIC PARTICIPATION

Below is a summary of the primary opportunities for public participation in the Squaw Creek TMDL process thus far:

- **August 24, 1999: Press Release Announcing Initiation of TMDL Process for Squaw Creek**

  The Lahontan Region Board issued a press release outlining plans to compile existing data on Squaw Creek and develop additional information on aquatic community health and sediment sources in support of a TMDL for sediment in Squaw Creek. The public was encouraged to participate in the process by contributing information on the watershed and joining the mailing list of interested stakeholders. The Regional Board project manager's contact information was provided to facilitate communication.

- **October 26, 2000: Squaw Valley Municipal Advisory Committee Meeting**

  Regional Board staff attended the Squaw Valley Municipal Advisory Committee (MAC) meeting to present information on the Squaw Creek Sediment TMDL. Regional Board staff provided background information on the TMDL and 303d-listing process (both generally and specific to Squaw Creek), along with information on stream restoration and measures of success. Staff from the Desert Research Institute (DRI) gave a talk on details of the Squaw Creek Sediment Source Assessment study plan. A question and answer session followed both presentations. MAC members are area residents, property owners, or business owners or managers, and as such represent a wide variety of stakeholder interests in the watershed.

- **August 20, 2002: Friends of Squaw Creek Meeting**

  Staff of the Regional Board, along with staff of DRI, presented the results of the Squaw Creek Sediment Source Assessment. Details on the study's findings were discussed, including active erosion processes and land uses in the watershed that have effected erosion and sedimentation to the creek. Approximately sixteen members of the Friends of Squaw Creek, a local watershed group, were in attendance.

- **January 26, 2005: CEQA Scoping Meeting**

  CEQA Section 21083.9 requires scoping meetings for projects of statewide, regional or areawide significance. The purpose of a scoping meeting is to provide a forum for lead agencies, jurisdictional agencies and interested parties to comment on the scope and content of the environmental information to be analyzed during the CEQA process. Regional Board staff held a scoping meeting for this project on January 26, 2005 at the Truckee Town Hall. Regional Board staff presented summaries of the Squaw Creek TMDL elements, and discussed potential methods of implementing the TMDL. Both oral and written comments were received from the participating stakeholders.

8.2 FUTURE TMDL PUBLIC PARTICIPATION

Prior to final submittal of the Squaw Creek Sediment TMDL to the Lahontan Regional Board and the USEPA, the public will be given the opportunity to review and comment on the TMDL to fulfill CEQA requirements discussed above. A workshop to discuss the public review draft is anticipated prior to public hearing for Regional Board adoption. All comments received will be considered in development of the TMDL, and formal responses will be available as part of the Regional Board agenda package for TMDL adoption, as well as contained in the administrative record for this project. This section will be updated to reflect our additional level of involvement in the stakeholder process as the TMDL proceeds.

9. IMPLEMENTATION AND MONITORING

9.1 REASONABLE ASSURANCE OF IMPLEMENTATION

USEPA's national policy is that all TMDLs are expected to provide reasonable assurances that they will be implemented in a manner that results in attainment of water quality standards. For nonpoint sources, reasonable assurance "means that nonpoint source controls are specific to the pollutant of concern, implemented according to an expeditious schedule, and supported by reliable delivery mechanisms and adequate funding" (USEPA, 1999). The sediment control actions outlined below in Section 9.2 are specific to the pollutant of concern, and are directly focused on the sources of that pollutant. Implementation is ongoing, and additional regulatory-based sedimentation controls will be drafted within six months of final TMDL adoption by the USEPA. Additional assurance of implementation is provided because the sediment loading reductions are based on low- to mid-range values of efficiencies for BMPs used widely in the Lake Tahoe basin, a similar environment to the Squaw Creek watershed, indicating that the reductions are technically and financially feasible and reasonably achievable.

In California, CWC Section 13242 requires that a plan of implementation be incorporated into the Basin Plan when the Regional Board adopts TMDLs. The implementation plan must include 1) a description of the nature of the actions necessary to achieve the water quality objectives, including recommendations for appropriate action by any entity, public or private, 2) a time schedule for the actions to be taken, and 3) a description of the monitoring and surveillance to be undertaken to determine compliance with the objectives. Therefore, CWC requirements provide the regulatory reasonable assurance that the TMDL will be implemented in a manner that attains the water quality standards.

9.2 IMPLEMENTATION PLAN

The Regional Board has regulatory authority to implement TMDLs under both the CWA and the CWC, including, but not limited to, adopting waste discharge requirements (WDRs), waivers of WDRs and stormwater and construction permits to control sediment discharges. Enforcement actions may be used to address water quality problems when Basin Plan provisions or WDRs or waivers are violated. These include Notices of Violation, Cleanup and Abatement Orders, Cease and Desist Orders, and monetary fines (administrative civil liabilities). Although the Regional Board cannot specify the design, location, type, or particular manner of compliance (CWC Section 13360), it can require dischargers to implement sediment and erosion controls such as BMPs necessary to attain the water quality standards through its regulatory authority.

Because much work to regulate and control sediment discharges in the Squaw Creek watershed has been accomplished in the past five years (i.e., <u>after</u> sediment impairment studies were initiated in 2000), it is reasonable to assume that current (2005) conditions in the watershed are improving over those documented in 2000 – 2001. It is expected that additional focus on certain key issues described in Section 9.2.1, and ongoing compliance with the existing regulatory efforts outlined in Section 9.2.2 will continue to improve conditions in Squaw Creek, resulting in TMDL attainment over time.

9.2.1 Issues of Additional Focus to Attain the TMDL

The majority of dischargers in the Squaw Creek watershed whose lands are identified as primary sediment sources are currently regulated by the Regional Board under WDRs; yet despite this, the control actions implemented have not been fully effective to protect water quality and aquatic life habitat. Most likely, this results from several factors: lack of focus on control of fine sediment; permit violation and compliance issues; and unregulated discharges of sediment. To address these issues, the TMDL implementation plan proposes additional focus on those areas. These focus issues are outlined here to guide Regional Board staff in developing permits and reviewing erosion control plans to comply with the TMDL, and to inform dischargers and the public of existing and recommended approaches to attain the TMDL.

Fine Sediment Control

Stream channel substrate sampling in Squaw Creek and reference sites identified the abundance of fine sediment (<1mm) in the meadow reach as problematic. BMPs used to control excessive sedimentation to stream channels can be divided into two general categories: erosion (or source) control and sediment (or treatment) control. Effective control of excessive sedimentation typically involves a combination of both erosion and sediment control. Erosion control focuses on preventing soil movement from occurring by increasing soil porosity and infiltration capacity, protecting soil surfaces from the energy of falling rain, binding soil particles together, and slowing runoff velocity. Erosion controls typically include mulches, vegetative covers, energy dissipaters, soil binders, and other manufactured soil covers.

Sediment control generally refers to treatment of sediment-laden runoff after erosion has occurred, and involves filtering or allowing sediment to settle out of runoff before discharge to stormwater conveyances or surface waters. Sediment controls typically include filtration devices and barriers (such as fiber rolls, silt fences, straw bales, gravel filters, and biofilters) and settling devices (such as sediment traps and detention basins). However, once erosion occurs, it is extremely difficult to capture the fine silt and clay fractions (Hogan, 2005), because fine sediments pass through many conventional filter media and are slow to settle out of runoff. However, sediment controls combined with aggressive erosion controls can be very effective in reducing sedimentation to streams.

Erosion controls are preferred as a first option for controlling sediment discharges because it is more effective to prevent soil erosion than it is to treat sediment-laden runoff. It is not possible to specify a ratio of erosion versus sediment control techniques that might result in the most effective overall BMP strategy. These decisions must be made on a site-by-site basis taking into account soil conditions, depth to bedrock, slope, runoff patterns, traffic and access issues, and maintenance needs. Regional Board staff will evaluate all sediment control plans with a focus on the use of erosion controls wherever possible, in combination with strategically located sediment controls to attain load reductions required by this TMDL.

Permit Compliance and Violation Issues

Regional Board staff has been active in monitoring and enforcing sediment-related permit violations in the watershed, including the issuance of a mountain-wide CAO to SVSC in 2001 and referral of Board order violations to the Attorney General's office. The CAO contained requirements to conduct a facilities assessment to identify and prioritize erosion control projects, implement facility-wide BMPs, and conduct biologic assessment monitoring in Squaw Creek. High priority erosion control projects identified in the Facilities Assessment were addressed through a Critical Water Quality Improvement Plan (CWQIP), implemented in 2003.

SVSC also proposed a longer-term Water Quality Improvement Plan (WQIP) to outline a schedule to implement remaining erosion control projects identified in the Facilities Assessment. The intent of the WQIP is to protect beneficial uses of Squaw Creek and its tributaries by using and enhancing natural processes such as riparian and wetland improvements/enhancements, stormwater runoff controls, erosion controls and revegetation. Additionally, a recent (July 2005) settlement agreement between SVSC, the Lahontan Regional Board and the Attorney General regarding water quality violations will facilitate progress to improve hillslope conditions in the Squaw Creek watershed. The settlement agreement contains requirements for a settlement payment, demonstration of success for previous mitigation projects, future project documentation submissions, and dispute resolution.

SVSC has made progress in implementing mountain-wide BMPs, conducting bioassessment monitoring and reporting. The WQIP approach proposed by SVSC is still under negotiation, subject to the dispute resolution process outlined in the settlement agreement. Implementation of the WQIP will be key to improving conditions in the watershed and attaining the TMDL; therefore, where possible, WQIP projects should focus on source control BMPs to limit the delivery of fine sediment to Squaw Creek.

Compliance with all WDRs issued in the watershed to control sediment discharges will needed to attain the TMDL. Regional Board staff will monitor and evaluate all dischargers' permit compliance histories together with the numeric target monitoring parameters when assessing TMDL attainment.

Additional Permitting Actions

The State Board's Nonpoint Source (NPS) Implementation and Enforcement Policy (SWRCB, 2004) requires the Regional Boards to regulate all NPS pollution. Regulation may be accomplished using Basin Plan prohibitions, WDRs, conditional waivers of WDRs, and other applicable authority. Most of the paved roads in the watershed are under the jurisdiction of Placer County, and no permit or waiver has been issued to regulate discharges related to road building or maintenance operations.

To implement TMDL load allocations for residential and commercial areas, and road sanding, WDRs (issued under either State or delegated federal NPDES permitting authority) will be issued to Placer County. WDRs will include provisions to identify sediment source areas and propose methods to control and/or treat stormwater and urban runoff discharges from those sources. Annual road sanding application and retrieval reports will be required to ensure that the required percent reduction from that sediment source category is met.

9.2.2 Existing Sediment Control Programs

Waste Discharge Requirements

Squaw Valley Ski Corporation and the Resort at Squaw Creek

WDRs were adopted under Board Order No. 6-93-25 for SVSC to control the discharge of waste sediment from its facility, including ski runs, dirt roads and parking lots. WDRs for The Resort at Squaw Creek (Board Order No.6-93-26A3) require control of waste sediment from its facility, including ski runs, dirt roads, golf course areas and parking lots. Generally, both dischargers are required to identify sources of erosion and sediment delivery, implement programs that minimize the disturbance of natural vegetation, and use BMPs such as revegetation, water bars, drop inlets and other sediment control measures to prevent waste earthen materials from entering surface waters. Examples of specific requirements related to erosion and sedimentation control, common to both permits, are listed below.

- Prior to any disturbance of existing soil conditions, install temporary erosion control facilities to prevent transport of eroded earthen materials.
- Vehicle use shall be restricted to existing roads and disturbed areas.
- All eroding slopes steeper than 2:1 (horizontal:vertical) shall be stabilized.
- All disturbed areas shall be adequately restabilized or revegetated.
- Surface flows from facilities shall be controlled so as not cause erosion.

Annual worklists of erosion control facilities, inspection dates, problems noted, and corrective measures are required. Full compliance with the requirements of the existing WDRs and monitoring and reporting programs for SVSC and the Resort at Squaw Creek are expected achieve the load allocations specified for all sediment source categories under the management of both facilities within the 20-year TMDL attainment schedule.

Intrawest Village at Squaw Valley – Phase I and II

In 2003, WDRs were issued to Intrawest California Holdings, Inc., for the Village at Squaw Valley (Board Order R6T-2003-0002) to regulate stormwater runoff from approximately 15 acres of development, of which approximately 9.5 acres are impervious (paved areas). Treated stormwater from Phase II of the Village is discharged to Squaw Creek rather than infiltrated due to local ground water protection requirements in place to protect the shallow drinking water aquifer. The discharger uses a combination of stormwater treatment and source control measures to protect water quality in Squaw Creek. The stormwater treatment system relies on sand/oil separators and vertical media filter technology designed to treat runoff generated by the 20-year, one-hour storm (i.e., flows up to about 5.5 cubic feet per second). The WDR monitoring program contains numeric effluent limits and receiving water limits set such that water quality objectives in Squaw Creek will not be exceeded. Full compliance with the requirements of the existing WDRs and monitoring and reporting programs for the Village at Squaw Creek are expected achieve the load allocations specified for all sediment source categories under its management within the 20-year TMDL attainment schedule.

<u>New Development Projects</u>

In 2003, the Regional Board developed General WDRs (Board Order R6T-2003-004) for small construction projects that involve at least 10,000 square-feet of land disturbance, but less than one acre. Proponents of these projects are required to obtain coverage under the General WDRs if they are located in the Truckee River Hydrologic Unit, which includes Squaw Creek. The General WDRs contain requirements to submit a BMP plan to evaluate potential sources of sediment and other pollutants at the construction site and put controls in place that will effectively prevent pollutant discharges to surface and ground waters. The following general sediment control requirements are addressed in the BMP plan:

- Retention of soil and sediment on the construction site;
- Prevention of non-stormwater discharges that would discharge pollutants off site;
- Permanent stabilization of disturbed soils; and
- Minimization of the effects of increased stormwater runoff from impervious surfaces.

All landowners in the Squaw Creek watershed proposing applicable construction projects must obtain coverage under this General Permit prior to commencement of construction activities. Because the permit requires the retention and stabilization of soil and sediment at the construction site, it is expected that meeting the requirements of the General WDRs will meet the load allocation assigned to future growth related to small (typically residential) construction projects.

National Pollutant Discharge Elimination System (NPDES) Permits

<u>New Development Projects</u>

The State Water Resources Control Board's (State Board's) General Permit for Discharges of Stormwater Associated with Construction Activity (99-08-DWQ) applies to dischargers whose projects disturb one or more acres of soil or whose projects disturb less than one acre but are part of a larger common plan of development that in total disturbs one or more acres. The General Permit requires all dischargers to:

- Develop and implement a Stormwater Pollution Prevention Plan (SWPPP) that specifies BMPs that will prevent all construction pollutants from contacting stormwater and with the intent of keeping all products of erosion from moving off-site into receiving waters;
- Eliminate or reduce non-stormwater discharges to storm sewer systems and other waters of the nation, and;
- Perform inspections of all BMPs.

It is the responsibility of the all applicable project proponents in the Squaw Creek watershed to obtain coverage under this General Permit prior to commencement of construction activities. To obtain coverage, the landowner must file a Notice of Intent (NOI) with a vicinity map and the appropriate fee with the Regional Board. Because the permit requires the retention and stabilization of soil and sediment at the construction site, it is expected that meeting the requirements of the permit will meet the load allocation assigned to future growth related to larger construction projects.

401 Water Quality Certification

Under the CWA section 401, every applicant for a federal permit or license for any activity that may result in a discharge to a water body must obtain State Water Quality Certification (Certification) that the proposed activity will comply with state water quality standards. Most 401 Certifications are issued in connection with U.S. Army Corps of Engineers CWA section 404 permits for dredge and fill discharges. Project proponents must describe and implement measures to avoid or minimize impacts to surface waters, including wetlands and riparian zones.

Cooperative and Voluntary Activities

There are active, ongoing efforts by local watershed groups such as the Truckee River Watershed Council (TRWC) and the Friends of Squaw Creek (FOSC). These groups propose and implement voluntary watershed enhancement projects for the Truckee River and its tributaries, including Squaw Creek. Entities such as Placer County, Squaw Valley Academy and several local businesses contribute time, funding and expertise to many of these cooperative efforts. Numerous projects are planned or have been implemented in the Squaw Creek watershed to control erosion, and improve stream function and riparian conditions (pers. comm., E. Heneveld, FOSC, May 28, 2005):

- Willow planting to stabilize stream channel banks along the meadow reach of Squaw Creek was conducted in 2002 and 2003. This project was part of Truckee River Day, sponsored by the TRWC.

- FOSC hosted a 2003 volunteer pine needle collection effort and educational forum to raise awareness of the value of pine needles in soil stabilization. The collected pine needles were used in demonstration hillslope erosion control projects in Squaw Valley.

- In 2003 and 2004, FOSC members worked with staff of SVSC's environmental team to maintain and consolidate hiking trails in Squaw Creek's north fork watershed, focusing on creekside trails where potential erosion issues were identified.

- FOSC worked cooperatively with Placer County's Department of Public Works and the Squaw Valley Academy in 2003 to clean and stabilize roadside swales and culverts in the Valley.

- FOSC, the Resort at Squaw Creek, Poulsen Commercial, SVSC and various regulatory agencies plan to host an annual Squaw Creek Day. In 2005, FOSC was awarded a grant from the Sierra Nevada Alliance to help fund this year's creek stewardship day, which is co-sponsored by the TRWC. The event will focus on tall whitetop (perennial pepperweed), an invasive weed identified in the Squaw Valley meadow area that displaces native vegetation, thus increasing soil erosion and water consumption. Education on how to identify, manage and eradicate this invasive species will be provided followed by hands-on work parties to remove the tall whitetop infestation in the meadow near the creek.

Lastly, Placer County awarded a contract in 2005 to study the feasibility of restoration projects to improve stream function in Squaw Creek. The focus will be on the eastern half of the meadow reach of Squaw Creek. Potential improvements are to restore the stream to its historic channel and improve stream substrate and bank conditions to improve aquatic habitat. The project is currently (as of summer 2005) in the scoping and conceptual design phase (pers.comm., E. Sullivan, Placer County, June 7, 2005).

Regional Board staff will continue to support and encourage these voluntary and cooperative efforts. This will be accomplished by providing technical advice, grant application assistance to secure project funding, and participation in watershed events. It is anticipated that continued implementation of riparian improvement projects such as those outlined above, combined with improving upslope conditions, will be adequate to meet the load allocation assigned to in-stream channel erosion.

9.3 MONITORING PROGRAM

The primary measure of success from implementation of this TMDL is attainment of the numeric targets. However, recognizing the variability inherent in the factors affecting sediment loading within the watershed, other measures of success will be considered in evaluating progress toward implementation of the TMDL. Therefore, two types of monitoring are proposed: 1) physical and biological habitat indicator monitoring, and 2) monitoring of sediment control actions, such as permit compliance including appropriate BMP implementation.

The numeric target monitoring program will be implemented by updating the existing monitoring and reporting programs of the dischargers currently under permit and assigning monitoring requirements to dischargers not currently under permit through the Regional Board’s regulatory authority. Generally, staff expects numeric target monitoring to be conducted either individually or cooperatively by dischargers in the watershed with operational WDRs. Dischargers who are issued short-term, project-specific WDRs (e.g., general construction WDRs) are not expected to contribute to the numeric target monitoring.

Regional Board staff will conduct surveillance monitoring to track implementation progress by assessing permit compliance and conducting field inspections. In general, this involves verifying that regulated dischargers identify their sediment source areas, prepare corrective action plans to mitigate those sources, and make appropriate progress to implement corrective action plans.

The numeric target monitoring plan is presented in Table 9-1, and the sediment control actions monitoring plan is shown in Table 9-2.

Table 9-1
Numeric Target Monitoring Plan

Indicators and Target Values	Monitoring Specifications	Responsible Monitoring Parties	Schedule
Physical Habitat Indicator: D-50 Particle Size. **Target Value:** Increasing trend approaching 40 mm or greater. **Physical Habitat Indicator:** Percent fines and sand. **Target Value:** Decreasing trend approaching 25 percent. **Biologic Health Indicator:** Biologic condition score, based on bioassessment data. **Target Value:** Biologic condition score of 25 or greater.	1. Establish 3 sampling sites (upper, middle, and lower) on the meadow reach of Squaw Creek 2. Conduct bioassessment sampling and calculate biologic condition score using Herbst (2002) protocol. 3. Analyze D-50 particle size using Herbst protocol. 4. All sampling protocols will be specified in WDRs.	• SVSC (existing permit) • Resort at Squaw Creek (existing permit) • Village at Squaw Creek (existing permit) • Placer County (Anticipated permit)	1. Regional Board to add monitoring requirements to existing WDR Monitoring & Reporting programs of permitted dischargers no later than six months after final approval of TMDL. 2. Regional Board to issue WDRs for Placer County stormwater discharges no later than six months after final approval of TMDL. 3. Each regulated discharger to conduct sampling individually or as agreed to cooperatively. 4. Numeric target sampling shall be conducted once every two years between the months of July and September when flow is continuous. 5. Progress toward attainment of the physical habitat targets to be evaluated by trend assessment, beginning after 3 consecutive sampling events have been completed. Trend assessment will be based on all monitoring data for each physical habitat indicator. 6. Attainment of the biologic condition score target will be assessed using 3-(sampling) event rolling average datasets. The biologic condition target will be met when the rolling average for three consecutive 3-event datasets meets or exceeds 25.

Table 9-2
Monitoring of Erosion and Sediment Control Actions(1)

Monitoring Parameter	Responsible Monitoring Party	Monitoring Schedule
Compliance with all permit requirements, including discharge specifications, BMP installation focusing on source control and maintenance, general requirements and prohibitions, monitoring, and reporting.	Regional Board staff	Assess permit compliance quarterly using Regional Board's permit tracking database currently in place. Assessment of numeric target data (collected as specified in permits) will occur according to schedule outlined in Table 9-1, above.
Facilities inspections to ensure permit compliance.	Regional Board staff	Regional Board staff to inspect all facilities twice annually.
TMDL data review and assessment.	Regional Board staff	As outlined in Section 9.4.

(1) Requirements may already be satisfied under existing WDRs.

9.4 SCHEDULE OF TMDL ATTAINMENT, DATA REVIEW, AND REVISION

The estimated time frame for meeting the numeric targets and achieving the TMDL is 20 years. This estimate takes into consideration time needed for dischargers to identify sediment sources, devise a plan to address those sources, and fully implement appropriate sediment controls. Further, there may be significant temporal disparities between upland erosion control actions and sediment delivery to the creek; therefore, this estimate accounts for the time needed for the target indicators to respond to decreased sediment loading.

Attainment of the biologic health target will be evaluated by the rolling average of biologic condition scores calculated from three consecutive sampling events. For example, if numeric target sampling begins in 2006, biologic condition data will be collected in 2006, 2008 and 2010. These data will be assessed in 2010 by averaging all biologic condition scores for each site collected over this period. Data collected in 2012 will be added to the dataset, and an average value for biologic condition scores collected in 2008, 2010 and 2012 will be calculated, and so on. The biologic condition target will be met when the rolling average for three consecutive 3-sampling event datasets meets or exceeds 25.

Progress toward meeting the physical habitat numeric targets will be evaluated by assessing the data trend for each indicator (decreasing trend for percent fines and sand, and increasing trend for D-50 particle size). Data assessment will begin after three sampling events have occurred. For example, if numeric target sampling commences in 2006, data will be collected in 2006, 2008, and 2010; therefore, in 2010, the data trend will be evaluated. Each subsequent sampling event's data will be added to the dataset for purposes of trend evaluation.

Permit compliance status will be assessed quarterly, using the Regional Board's permit compliance tracking database currently in place, and through semi-annual field inspections. Compliance information will be taken into account when assessing the need for any revisions to targets or TMDL implementation. During the 10-year data review (the halfway point estimated for TMDL attainment), staff shall examine all data trends to determine the need for revision of the TMDL, numeric targets, or implementation plan. Revisions to the WDRs, NPDES permits, or other regulatory actions shall be made as warranted to ensure that applicable water quality objectives and beneficial uses are attained.

Acronym and Abbreviation List

AMSL	Above Mean Sea Level
AnnAGNPS	Annual Agricultural Nonpoint Source Model
BCS	Biologic Condition Score
BMI	Benthic Macroinvertebrates
BMP	Best Management Practices
CAO	Cleanup and Abatement Order
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
CFR	Code Of Federal Regulations
CWA	Clean Water Act
CWQIP	Critical Water Quality Improvement Plan
D-50	Median Particle Diameter
DEM	Digital Elevation Model
DOQ	Digital Orthophotoquad
DRI	Desert Research Institute
EPT	Ephemeroptera, Plecoptera, Tricoptera (mayfly, stonefly, caddisfly)
FOSC	Friends of Squaw Creek
GIS	Geographic Information System
GPS	Global Positioning System
IBI	Index of Biological Integrity
LA	Load Allocation
LCT	Lahontan Cutthroat Trout
MAC	Municipal Advisory Committee
MOS	Margin of Safety
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
PPT	Precipitation
R-50	Number of taxa required to reach 50 percent (half) of the ranked abundance of all organisms
RWQCB	Regional Water Quality Control Board
SDR	Sediment Delivery Ratio
SNARL	Sierra Nevada Aquatic Research Laboratory
SSC	Suspended Sediment Concentration
SVSA	Squaw Valley USA Ski Area
SVSC	Squaw Valley Ski Corporation
SWPPP	Stormwater Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
TRWC	Truckee River Watershed Council
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture

USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
WDR	Waste Discharge Requirements
WLA	Waste Load Allocation
WQIP	Water Quality Improvement Plan
WQO	Water Quality Objectives

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